A. Bell Sculp.

NATURAL HISTORY,

GENERAL AND PARTICULAR,

BY THE

COUNT DE BU[redacted]

TRANSLATED INTO ENGLISH,

ILLUSTRATED

WITH ABOVE THREE HUNDRED COPPER-PLATES,

AND OCCASIONAL

NOTES AND OBSERVATIONS,

By WILLIAM SMELLIE,

MEMBER OF THE ANTIQUARIAN AND ROYAL
SOCIETIES OF EDINBURGH.

THE THIRD EDITION,

IN NINE VOLUMES.

VOL. I.

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MDCCXCI.

TO THE

COUNT DE BUFFON,

&c. &c. &c.

SIR,

YOU did me honour by permitting me to addreſs to you my Tranſlation of your illuſtrious work; and I am proud to exerciſe the privilege you ſo politely conferred upon me. The important Information it contains, and the Eloquence of its compoſition, joined to the Ingenuity, Taſte, and Erudition, with which it abounds, induced me to

think that a Verſion of it into the Engliſh language, by diffuſing the knowledge of Nature, would increaſe the number of her admirers. The taſk, it muſt be acknowledged, was arduous; but your approbation and encouragement, by redoubling my vigour, diminiſhed the difficulty of the labour.

It was with the livelieſt pleaſure that I received your communications reſpecting the valuable Performances you have already publiſhed, and concerning thoſe great undertakings which now engage your attention. I failed not to announce to your friends in this country the advantages which Science and Literature have yet to expect from you; and I need hardly obſerve, that their wiſhes and my own, for the accompliſhment of your purpoſes, are in proportion to the greatneſs of your talents.

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The ſucceſs which the Tranſlation has met with, I impute to the celebrity of your name, and to the high value of the original.

I have the honour to be, with the moſt entire reſpect,

SIR,

Your moſt obedient, and

Moſt humble ſervant,

EDINBURGH,
May 10, 1781.

WILLIAM SMELLIE.

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PREFACE,

BY THE TRANSLATOR.

NATURAL HISTORY is the moſt extenſive, and perhaps the moſt inſtructive and entertaining of all the ſciences. It is the chief ſource from which human knowledge is derived. To recommend the ſtudy of it from motives of utility, were to affront the underſtanding of mankind. Its importance, accordingly, in the arts of life, and in ſtoring the mind with juſt ideas of external objects, as well as of their relations to the human race, was early perceived by all nations in their progreſs from rudeneſs to refinement.

But, notwithſtanding the great advantages to be derived from the knowledge of Nature, Ariſtotle is the only ancient writer on ZOOLOGY who merits attention. Inſtead of retailing fictions, or facts founded upon ignorance and credulity, he inveſtigated the relations and differences which connect and diſtinguiſh the various tribes of animals. What had been only a chaos of detached, uncertain, and often fabulous, narrations and deſcriptions, he reduced into a ſcientific form, with a ſucceſs ſo amazing, that, to this hour,

hour, no ſyſtematic view of animated beings has been attempted, the principles of which have not been adopted from Ariſtotle's hiſtory of animals. His analogies and diſtinctions are taken not only from the inſtruments of motion, the teeth, the eyes, the heart, and other external and internal organs of the body, to which the attention of our modern methodiſts has been chiefly confined, but from magnitude, figure, manners, faculties, and diſpoſitions of mind. He attempted not to arrange and define every known ſpecies. This labour he left to men of leſs genius and more patience. His work conſiſts entirely of philoſophical diſſertations on the general ſtructure, manners, and diſpoſitions of animals; and his particular facts are always employed to ſupport the principles which he is endeavouring to eſtabliſh.

Pliny and Ælian, though they had the illuſtrious example of Ariſtotle before them, produced nothing but crude collections, without diſcovering much taſte, judgment, or knowledge of the ſubject.

From this period, till the voluminous Geſner and Aldrovandus appeared, the knowledge of Nature, like other branches of literature, was involved in the general gloom of ignorance and ſuperſtition. It was the object of theſe authors to amaſs every thing that had been ſaid of animals by poets, ſhepherds, grammarians, philoſophers, phyſicians, and old women. Their pro-

lixity, of courſe, is inſufferable. Their labours, however, may be regarded as rude quarries, from which ſome valuable materials may be dug; but the expence of removing the rubbiſh will, perhaps, overbalance their intrinſic value.

In the ſame claſs, with little exception, may be ranked, Wotton, Belon, Rondeletius, Salvianus, Johnſon, and a multitude of ſimilar writers. They all tranſcribed, and ſometimes abridged, the labours of their predeceſſors; but they uniformly loſt ſight of philoſophy and ſcience.

This race of phlegmatic writers was ſucceeded by our celebrated countrymen Mr. Ray and Mr. Willoughby, who were admirers of Nature, and lamented the ſlovenly dreſs in which ſhe had been formerly exhibited. They knew the value of her treaſures, and wiſhed to ſhow them in their native brilliancy. They rejected dubious and fictitious relations. They added, from obſervation and experiment, many new facts: They arranged animals under proper claſſes and ſubdiviſions: They deſcribed with accuracy and preciſion: They pointed out the importance of the ſcience, and recommended the ſtudy of it by the ſolidity and clearneſs of their views, and by the brevity and perſpicuity of their compoſitions. This taſte continued ſome time, and produced the Works of Reaumur, Trembley, Buffon, and ſimilar publications.

From beginnings ſo proſperous, much was to be expected. But the excellency of method was

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no sooner recognised, than the philosophy of the science was nearly extinguished by a profusion of new terms and arrangements. The justly celebrated Linnæus, by persevering industry, joined to the utility of his technical dictionary*, unfortunately turned the attention of most naturalists, though contrary to the learned author's design, from the great views of Nature to the humble ambition of system-making. It is needless to specify examples. Every philosopher must have observed, with regret, that inundation of methodical distributions which have successively appeared during the course of these last thirty or forty years. Since Linnæus's works were published, the attention of Naturalists has been principally occupied with criticising former arrangements, and fabricating new ones. The philosophy of the science has, of course, been almost totally neglected. Naturally history has been exhibited in its most forbidding aspect, which has limited the study of it to a few, and these often not of the most brilliant talents; for it has been remarked, that the parade of learning, resulting from technical phrases and definitions, allure some men to become what is called *great naturalists*, whose chief knowledge of Nature is the knack of being able to name, with facility, a great number of her productions.

* Systema Naturæ, which, with regard to quadrupeds, can be considered in no other light.

This

This propenſity for multiplying methodical diſtributions, and diſputing about their reſpective merits, has brought much obloquy on the ſcience of Nature. Men of ſenſe perceive the folly of diſcuſſions concerning the local ſituation of an animal in a book. They conſider the authors as learned triflers; and, what is worſe, they are apt to regard a ſubject, which affords no better entertainment or information, as barren and unprofitable. To no other ſource can we aſcribe the following ſentiments, ſo frequently expreſſed by men of no inconſiderable talents: 'That natural hiſtorians have ſeldom 'diſcovered extenſive views; that they confine 'their chief attention to the mere technical part 'of the ſcience; that they rarely take notice of 'manners and inſtincts, or the cauſes and œco'nomy of animal action; and that they never 'purſue theſe great and uſeful objects with a 'degree of taſte and philoſophical accuracy, pro'portioned to the importance of the ſubject.' Theſe ſtrictures are common: I wiſh that they had no foundation in truth.

In natural hiſtory, two ends only can be attained by ſyſtem. Both of them are uſeful; but they are extremely different in their kinds. Syſtem may be employed either to facilitate the diſtinction of objects, or to aſcertain their relations in the ſcale of being.

The firſt ſpecies of ſyſtem, it is obvious, muſt conſiſt entirely of a ſeries of external or inter-

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nal characters. It is of little moment, whether the objects ranked under particular ORDERS be mutually connected; because, if we may judge from the many laborious, but abortive, attempts which have been made, Nature seems not to have expressed such connections in characters recognisable by our senses. A system so limited in its principles and design, can never assume any other form than that of a technical index or dictionary. If the general and particular characters be so marked, that a student, after learning the divisions and language of the author, can investigate the proper names of the objects presented to him, this system is perfect; because its sole and primary intention is fulfilled.

Were every naturalist of the same sentiments with regard to this point, many incumbrances, which now load the science, would be removed; the tyro would not be disgusted and retarded by an infinity of synonimes; natural history would acquire a more simple and intelligible form; and the number of its votaries would soon be augmented.

The second species of system is more elevated and sublime. But, as it includes the whole philosophy of Nature, it requires a depth of judgment, a superiority of genius, an extent of knowledge, which are seldom united in the same person. Natural objects are wonderfully diversified in their structure, œconomy, and faculties. But, in these, as well as in many other circumstances,

ſtances, they are no leſs wonderfully connected. Here, then, are foundations for conſtructing the ſyſtem of Nature. To mark the diſtinctions, to inveſtigate the relations, to aſcertain the great chain that unites the numerous tribes which people and adorn the univerſe, would demand talents ſuperior, perhaps, to thoſe of humanity. We ought not, however, to deſpair. Hardly any bounds can be ſet to the combined force of different minds acting ſucceſſively upon the ſame ſubject. Something has already been done. More may in time appear: Nature, in ſome future period, may happily unite philoſophy and Natural Hiſtory, a phænomenon which has hitherto been but partially exhibited.

Among thoſe authors, whether ancient or modern, who have contributed to unfold the philoſophy of Natural Hiſtory, the COUNT DE BUFFON holds the moſt diſtinguiſhed rank. This learned and eloquent writer has introduced into his ſubjects a greater variety of diſquiſition, and given more comprehenſive views of Nature, than any preceding or contemporary hiſtorian. His facts are, in general, collected with judgment and fidelity; and his reaſonings and inferences are not only bold and ingenious, but adorned with all the beauties of expreſſion, and all the charms of novelty. They every where lead to reflections which are momentous and intereſting. They expand the mind and baniſh prejudices. They create an elevation of thought,

and

and cheriſh an ardour of inquiry. They open many great and delightful proſpects of the œconomy of Nature, of the alterations and accidents to which ſhe is liable, of the cauſes of her improvement or degeneration, and of the general relations that connect the whole, and give riſe to all the diverſities which characteriſe and conſtitute particular orders of exiſtence.

The original work, of which I have attempted a tranſlation, was undertaken and carried into execution under the munificent encouragement of a great monarch. The deſign was to compoſe a hiſtory which ſhould record not only every phænomenon in the univerſe that was already known, but to examine, deſcribe, and delineate from the life, all the animals which could be procured by royal influence. A plan ſo extenſive required the joint operation of, at leaſt, two perſons: the one to compoſe the hiſtorical part, the other to diſſect and minutely deſcribe every animal, both native and foreign, that ſhould be obtained. The literary character and philoſophic talents of the COUNT DE BUFFON pointed him out for the execution of the firſt department; and the acuteneſs and anatomical ſkill of M. DAUBENTON recommended him for that of the ſecond.

Three volumes of this great work were given to the public in the year 1749. Theſe volumes exhibited ſuch diſplays of learning, taſte, genius, and eloquence, as procured to the author uncommon

common admiration; and excited a ſtrong and general deſire for the completion of his plan; which, however, from various cauſes, was not accompliſhed till the year 1767.

The COUNT DE BUFFON, in the year 1776, favoured the world with a ſupplementary volume to his hiſtory of quadrupeds, which, beſide an ingenious diſſertation on Mules, contains the hiſtory and figures of ſeveral new animals, and valuable additions to moſt of thoſe deſcribed in the original publication.

It would be improper to enter more minutely into the hiſtory or contents of this magnificent work. Such is the fertility of the author's genius, and ſuch his ardour for philoſophic inquiry, that, when treating of the moſt common animals, he often aſtoniſhes his reader with the profoundneſs of his remarks, and the beauty of his analogical diſcuſſions.

But, though the publication was a great acquiſition to literature; yet the high price of SIXTEEN GUINEAS, which was an unavoidable conſequence of its ſplendour, and of the prodigious number of its elegant engravings, confined its utility to men of opulence. Senſible of this inconvenience, the COUNT DE BUFFON, a few years ago, publiſhed an edition in 12*mo*; and, to bring it within the reach of common purchaſers, he excluded from it the long and minute anatomical diſſections and menſurations.

After this ſhort ſketch of the COUNT DE BUFFON's Hiſtory of Nature, it may ſeem ſtrange

that no decent tranſlation of it has hitherto appeared in the Engliſh language. To ſuch an undertaking, the great expence of the engravings was one ſolid objection. Another aroſe from the vaſt variety of learning employed by the author. When to theſe are added the exuberance of his fancy, the eloquence and force of his diction, the delicacy and ſubtleneſs of his diſquiſitions, we ſhould rather wonder how any man could reconcile himſelf to a taſk ſo laborious, and which required the union of ſuch diverſified talents.

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This tranſlation comprehends what is contained in the original fifteen volumes in quarto, together with the ſupplementary volume to the hiſtory of quadrupeds, except the deſcription of the King's cabinet, the dry and unintereſting anatomical diſſections and menſurations, which can be of little uſe but to profeſſed anatomiſts, and have been properly omitted by the author in the laſt Paris edition. The method of ſtudying Natural Hiſtory; the reprehenſion of methodical diſtributions; and the mode of deſcribing animals, are likewiſe omitted. The chief intention of theſe diſcourſes is to ridicule the authors of ſyſtematic arrangements, and particularly the late ingenuous and indefatigable Sir Charles Linnæus, whoſe zeal and labours in promoting the inveſtigation of natural objects merit the higheſt applauſe.

applause. There is a stronger reason for this omission: The same remarks and arguments are, perhaps, too frequently repeated in the history of particular animals.

To render this English version more valuable, the translator has added short distinctive descriptions to each species of quadrupeds. For these he has been indebted to the labours of the learned and ingenious Mr. Pennant. Beside these useful additions, the synonimes, and the generic and specific characters given by Linnæus, Klein, Brisson, and other naturalists, are subjoined to the description of each species.

Where the author commits mistakes, or where he recommends practices, regarding the management of particular animals, which differ from those observed in this country, the translator has taken the liberty of animadverting upon such passages in notes: But he has seldom taken any notice of peculiar theories or doctrines. These must rest upon the facts and arguments employed by the author. It was not the intention of the translator to write a commentary upon his original.

The great variety of subjects discussed by the Count de Buffon, has already been mentioned. It is almost unnecessary to remark, that every subject demands a peculiar style. A bare enumeration of facts, or descriptions of the dimensions, figure, and colour of animals, admit of no other ornament than that of perspicuity. Topics of philosophy and argument require a higher and

more figurative expreſſion: And addreſſes to the paſſions, and the finer feelings of men, give full ſcope to the exercife of genius and of taſte. Of theſe different ſpecies of writing, the examples are numerous in the works of the COUNT DE BUFFON. The tranſlator has endeavoured to follow the original, as far as his abilities would permit. The degree of ſucceſs he has attained muſt be ſubmitted to the impartial determination of the public. He ſhall only ſay, that his apprehenſions, though he is conſcious of no voluntary negligence, are much greater than his hopes.

N. B. Since the firſt edition was printed, the Count de Buffon has publiſhed another ſupplementary volume. It conſiſts chiefly of curious and intereſting facts with regard to the hiſtory of the earth. Theſe the Tranſlator has added in a ſeparate volume, which, to accommodate the purchaſers of the former edition, he has directed to be ſold by itſelf.

*** In the dimenſions of animals, the tranſlator has retained the French meaſures. The differences between the foot or inch of England and France are ſo inconſiderable, when applied to individual animals, that he thought it unneceſſary to reduce them to the preciſe Engliſh ſtandard, eſpecially as the dimenſions are Engliſh in the deſcriptions added in the notes.

THE

HISTORY AND THEORY

OF THE

A R T H.

THE figure of the earth*, its motions, or the external relations which ſubſiſt between it and the other parts of the univerſe, belong not to our preſent inquiry. It is the internal ſtructure of the globe, its form and manner of exiſtence, which we here propoſe to examine. The general hiſtory of the earth ought to precede that of its productions. Details of particular facts relating to the oeconomy and manners of animals, or to the culture and vegetation of plants, are not, perhaps, ſo much the objects of natural hiſtory, as general deductions from the obſervations that have been made upon the different materials of which the earth itſelf is compoſed; as its heights, depths, and inequalities; the motions of the ſea, the direction of mountains, the ſituation of rocks and quarries, the rapidity and effects of currents in the ocean, &c.

* See ſubſequent proofs of the theory of the earth, art. I.

This is the hiſtory of Nature at large, and of her principal operations, by which every other inferior or leſs general effect is produced. The theory of theſe effects conſtitutes what may be called the primary ſcience, upon which a preciſe knowledge of particular appearances, as well as of terreſtrial ſubſtances, ſolely depends. This ſpecies of ſcience may be conſidered as appertaining to phyſics; but, is not all phyſical knowledge, where ſyſtem is excluded, a part of the hiſtory of nature?

In ſubjects of an extenſive kind, the relations of which it is difficult to trace, where ſome facts are but partially known, and others obſcure, it is more eaſy to form a fanciful ſyſtem, than to eſtabliſh a rational theory. Thus the theory of the earth has never hitherto been treated but in a vague and hypothetical manner. I ſhall, therefore, exhibit a curſory view only of the notions of ſome authors who have written upon this ſubject.

The firſt hypotheſis I ſhall mention is more conſpicuous for its ingenuity than ſolidity. It is the production of an Engliſh aſtronomer*, who was an enthuſiaſtic admirer of Sir Iſaac Newton's ſyſtem of philoſophy. Convinced that every poſſible event depends upon the motions and direction of the ſtars, he endeavours to prove, by means of mathematical calculations,

* Whiſton. See the proofs, art. II.

that all the changes this earth has undergone have been produced by the tail of a comet.

For another hypothesis we are indebted to a heterodox divine *, whose brain was so fully impregnated with poetical illusions, that he imagined he had seen the universe created. After telling us the state of the earth when it first sprung from nothing, what changes have been introduced by the deluge, what the earth has been, and what it now is, he assumes the prophetic style, and predicts what will be its condition after the destruction of the human kind.

A third writer †, a man of more extensive observation than the two former, but equally crude and confused in his ideas, explains the principal appearances of the globe by the aid of an immense abyss in the bowels of the earth, which, in his estimation, is nothing but a thin crust inclosing this vast ocean of fluid matter.

These hypotheses are all constructed on tottering foundations. The ideas they contain are indistinct, the facts are confounded, and the whole is a motley jumble of physics and fable. They, accordingly, have never been adopted but by men who embrace opinions without examination, and who, incapable of distinguishing the degrees of probability, are more deeply impressed with marvellous chimeras than with the genuine force of truth.

* Burnet. See proofs, art. III.

† Woodward. See proofs, art. IV.

My ideas on this ſubject will be leſs extraordinary, and may even appear unimportant, when compared with the grand ſyſtems of ſuch hypothetical writers. But it ſhould not be forgotten, that it is the buſineſs of an hiſtorian to deſcribe, not to invent; that no gratuitous ſuppoſitions are to be admitted in ſubjects which depend upon fact and obſervation; and that, in hiſtorical compoſitions, the imagination cannot be employed, except for the purpoſe of combining obſervations, of rendering facts more general, and of forming a connected whole, which preſents to the mind clear ideas, and probable conjectures: I ſay, probable; for it is impoſſible to give demonſtrative evidence on this ſubject. Demonſtration is confined to the mathematical ſciences. Our knowledge in phyſics and natural hiſtory depends entirely on experience, and is limited to the method of reaſoning by induction.

With regard to the hiſtory of the earth, therefore, we ſhall begin with ſuch facts as have been univerſally acknowledged in all ages, not omitting thoſe additional truths which have fallen within our own obſervation.

The ſurface of this immenſe globe exhibits to our obſervation heights, depths, plains, ſeas, marſhes, rivers, caverns, gulfs, volcano's; and, on a curſory view, we can diſcover, in the diſpoſition of theſe objects, neither order nor regularity. If we penetrate into the bowels of the

earth,

earth, we find metals, minerals, ſtones, bitumens, ſands, earths, waters, and matter of every kind, ſeemingly placed by mere accident, and without any apparent deſign. Upon a nearer and more attentive inſpection, we diſcover ſunk mountains*, caverns filled up, ſhattered rocks, whole countries ſwallowed up, new iſlands emerged from the ocean, heavy ſubſtances placed above light ones, hard bodies incloſed within ſoft bodies; in a word, we find matter in every form, dry and humid, warm and cold, ſolid and brittle, blended in a chaos of confuſion, which can be compared to nothing but a heap of rubbiſh, or the ruins of a world.

Theſe ruins, however, we inhabit with perfect ſecurity. The different generations of men, of animals, and of plants, ſucceed one another without interuption: The productions of the earth are ſufficient for their ſuſtenance; the motions of the ſea, and the currents of the air, are regulated by fixed laws †; the returns of the ſeaſons are uniform, and the rigours of winter invariably give place to the verdure of the ſpring. With regard to us, every thing has the appearance of order: The earth, formerly a chaos, is now a tranquil, an harmonious, a delightful habitation, where all is animated and governed by

* See Senec. Quaeſt. lib. 6. cap. 21. Strab. Geog. lib. 1. Oroſius, lib. 2. cap. 18. Plin. lib. 2. cap. 19. Hiſt. de l'acad. des ſciences, année 1708, p. 23.

† See the proofs, art. XIV.

ſuch amazing diſplays of power and intelligence, as fill us with admiration, and elevate our minds to the contemplation of the great Creator.

But let us not decide precipitantly concerning the irregularities on the ſurface of the earth, and the apparent diſorder in its bowels: We ſhall ſoon perceive the utility, and even the neceſſity of this arrangement. With a little attention, we ſhall perhaps diſcover an order of which we had no conception, and general relations that cannot be apprehended by a ſlight examination. Our knowledge, indeed, with regard to this ſubject, muſt always be limited. We are entirely unacquainted with many parts of the ſurface of this globe *, and have partial ideas only concerning the bottom of the ocean, which, in many places, has never been ſounded. We can only penetrate the rind of the earth. The greateſt caverns †, the deepeſt mines ‡, deſcend not above the eight thouſandth part of its diameter. Our judgment is therefore confined to the upper ſtratum, or mere ſuperficial part. We know, indeed, that, bulk for bulk, the earth is four times heavier than the ſun: We likewiſe know the proportion its weight bears to that of the other planets. But ſtill this eſtimation is only relative. We have no ſtandard. Of the real weight of the materials we are ſo ignorant, that the internal part of the globe may be either

* See proofs, art. VI. † Phil. tranſ. abridged, vol. ii. p. 323. ‡ Boyle's works, vol. iii. p. 232.

a void

a void ſpace, or it may be compoſed of matter a thouſand times heavier than gold. Neither is there any method of making farther diſcoveries on this ſubject. It is even with difficulty that rational conjectures can be formed *.

We muſt therefore confine ourſelves to an accurate examination and deſcription of the ſurface of the earth, and of ſuch inconſiderable depths as we have been able to penetrate. The firſt object which attracts attention, is that immenſe collection of waters with which the greateſt part of the globe is covered. Theſe waters occupy the loweſt grounds; their ſurface is always level; and, notwithſtanding their uniform tendency to equilibrium and reſt, they are kept in perpetual agitation by a powerful agent †, which counteracts their natural tranquillity, which communicates to them a regular periodic motion, alternately elevating and depreſſing their waves, and which produces a concuſſion or vibration in the whole maſs, even to the moſt profound depths. This motion of the waters is coëval with time, and will endure as long as the ſun and moon, by which it is produced.

In examining the bottom of the ſea, we perceive it to be equally irregular as the ſurface of the dry land ‡. We diſcover hills and valleys, plains and hollows, rocks and earths of every

* See proofs, art. I.

† Proofs, art. XII.

‡ Proofs, art. XIII.

 kind:

kind *: We diſcover, likewiſe, that iſlands are nothing but the ſummits of vaſt mountains, whoſe foundations are buried in the ocean †; we find other mountains whoſe tops are nearly on a level with the ſurface of the water; and rapid currents which run contrary to the general movement ‡. Theſe currents ſometimes run in the ſame direction; at other times their motion is retrograde ‖; but they never exceed their natural limits, which ſeem to be as immutable as thoſe which bound the efforts of land-rivers. On one hand, we meet with tempeſtuous regions, where the winds blow with irreſiſtible fury, where the heavens and the ocean, equally convulſed, are mixed and confounded in the general ſhock; violent inteſtine motions, tumultuous ſwellings §, water-ſpouts **, and ſtrange agitations, produced by volcano's, whoſe mouths, though many fathoms below the ſurface, vomit forth torrents of fire, and puſh, even to the clouds, a thick vapour, compoſed of water, ſulphur, and bitumen; and dreadful gulphs or whirlpools ††, which ſeem to attract veſſels for no other purpoſe than to ſwallow them up. On the other hand, we diſcover vaſt regions of an oppoſite nature, always ſmooth and calm, but

* See M. Buache's chart of the depths of the ocean between Africa and America. † Varenii Geog. gen. p. 218.

‡ Proofs, art. XIII. ‖ Varen. p. 140. and Voyages de Pirard, p. 137. § Shaw's travels. ** Proofs, art. XVI.

†† The Maleſtroom in the Norwegian ſea.

equally

equally dangerous to the mariner *. Here the winds never exert their force; the nautical art is of no utility; the becalmed voyagers muſt remain immoveably fixed, till death relieve them from miſery. To conclude, directing our eyes toward the ſouthern or northern extremities of the globe, we diſcover huge maſſes of ice †, which, detaching themſelves from the polar regions, advance, like floating mountains, to the more temperate climates, where they diſſolve and vaniſh from our view ‡.

Beſide theſe grand objects, the ocean preſents us with myriads of animated beings, almoſt infinite in variety: Some, clothed in light ſcales, ſwim with amazing ſwiftneſs; others, loaded with thick ſhells, trail heavily along, leaving their traces in the ſand: To others Nature has given fins reſembling wings, with which they ſupport themſelves in the air, and fly before their enemies to conſiderable diſtances. Laſtly, the ſea gives birth to other animals, which, totally deprived of motion, live and die immoveably fixed to the ſame rocks: All, however, find abundance of food in this fluid element. The bottom of the ocean, and the ſhelving ſides of rocks, produce plentiful crops of plants of many different ſpecies; its ſoil is compoſed of ſand, gravel, rocks, and ſhells; in ſome places, it is a fine clay, in others, a compact earth; and, in general, the bottom of the ſea has an

* The calms and tornados in the Æthiopan ſea.

† Proofs, art. VI. and X.

‡ See Buache's chart, 1739.

exact

exact reſemblance to the dry land which we inhabit.

Let us next take a view of the land: What prodigious differences take place in different climates! What a variety of ſoils! What inequalities in the ſurface! But, upon a more attentive obſervation, we ſhall perceive, that the great chains of mountains lie nearer the equator than the poles *; that, in the Old Continent, their direction is more from eaſt to weſt than from ſouth to north; and that, on the contrary, in the New Continent, they extend more from north to ſouth than from eaſt to weſt. But, what is ſtill more remarkable, the figure and direction of theſe mountains, which have a moſt irregular appearance †, correſpond ſo wonderfully, that the *prominent* angles of one mountain are conſtantly oppoſite to the *concave* ‡ angles of the neighbouring mountain ||, and of equal dimenſions, whether they be ſeparated by an extenſive plain, or a ſmall valley. I have further remarked, that oppoſite hills are always nearly of the ſame height; and that mountains generally occupy the middle of continents, iſlands, and promontories, dividing them by their greateſt lengths §. I have likewiſe traced the courſes of the principal rivers, and find that their direction is nearly perpendicular to the ſea-coaſts into which they empty themſelves; and that, during the

* Proofs, art. IX. † Ibid. art. IX. XII. ‡ *Saliant* and *re-entering* angles; Muller's fortification. || Lettres Phil. de Bourguet, p. 181. § Varen. Geog. p. 69.

greateſt

greateſt part of their courſes, they follow the direction of the mountains from which they derive their origin *. The ſea-coaſts are generally bordered with rocks of marble and other hard ſtones, or rather with earth and ſand accumulated by the waters of the ſea, or brought down and depoſited by rivers. In oppoſite coaſts, ſeparated only by ſmall arms of the ſea, the different ſtrata or beds of earth are of the ſame materials †. I find that volcano's never exiſt but in high mountains ‡; that a great number of them are entirely extinguiſhed; that ſome are connected with others by ſubterranean paſſages, and their eruptions not unfrequently happen at the ſame time ||. There are ſimilar communications between certain lakes and ſeas. Some rivers ſuddenly diſappear §, and ſeem to precipitate themſelves into the bowels of the earth. We likewiſe find certain mediterranean or inland ſeas, which conſtantly receive, from many and great rivers, prodigious quantities of water, without any augmentation of their bounds, probably diſcharging, by ſubterraneous paſſages, all theſe extraneous ſupplies. It is likewiſe eaſy to diſtinguiſh lands which have been long inhabited, from thoſe new countries where the earth appears in a rude ſtate, where the rivers are full of cataracts, where the land is either nearly overflowed with water, or burnt up with drought, and where every place

* Proofs, art. X. † Ibid. art. VII. ‡ Ibid. art. XVI.
|| Kircher Mund. ſubter. in praef. § Varen. Geog. p. 43.

capable

capable of producing trees is totally covered with wood.

Proceeding in our examination, we difcover that the upper ftratum of the earth is univerfally the fame fubftance *; that this fubftance, from which all animals and vegetables derive their growth and nourifhment, is nothing but a compofition of the decayed parts of animal and vegetable bodies, reduced into fuch fmall particles that their former organic ftate is not diftinguifhable. Penetrating a little deeper, we find the real earth, beds of fand, lime-ftone, clay, fhells, marble, gravel, chalk, &c. Thefe beds are always parallel to each other †, and of the fame thicknefs through their whole extent. In neighbouring hills, beds or ftrata of the fame materials are uniformly found at the fame levels, though the hills be feparated by deep and large valleys. Strata of every kind, even of the moft folid rocks, are uniformly divided by perpendicular fiffures ‡. Shells, fkeletons of fifhes, marine plants, &c. are often found in the bowels of the earth, and on the tops of mountains ||, even at the greateft diftances from the fea. Thefe fhells, fifhes, and plants, are exactly fimilar to thofe which exift in the ocean. Petrified fhells are to be met with, almoft every where, in prodigious quantities: They are not only inclofed in rocks of marble and lime-ftone, as

* Proofs, art. VII. † Ibid. and Woodward, p. 41. &c.
‡ Proofs, art. VIII. || Proofs, art. VIII.

well

well as in earths and clays, but are actually incorporated and filled with the very ſubſtances in which they are incloſed. In fine, I am convinced, by repeated obſervation, that marbles, lime-ſtones, chalks, marles, clays, ſand, and almoſt all terreſtrial ſubſtances, wherever ſituated, are full of ſhells and other ſpoils of the ocean*.

Having enumerated theſe facts, let us try what concluſions can be drawn from them.

The changes which the earth has undergone during the laſt two or three thouſand years are inconſiderable, when compared with the great revolutions which muſt have happened in thoſe ages that immediately ſucceeded the creation. For, as terreſtrial ſubſtances could only acquire ſolidity by the continued action of gravity, it is eaſy to demonſtrate, that the ſurface of the earth was at firſt much ſofter than it is now; and, conſequently, that the ſame cauſes, which at preſent produce but ſlight and almoſt imperceptible alterations during the courſe of many centuries, were then capable of producing very great revolutions in a few years. It appears, indeed, to be an incontrovertible fact, that the dry land which we now inhabit, and even the ſummits of the higheſt mountains, were formerly covered with the waters of the ſea; for ſhells, and other marine bodies, are

* Steno, Woodward, Ray, Bourguet, Scheuchzer, Phil. Tranſ. Mem. de l'Acad. &c.

ſtill found upon the very tops of mountains. It likewiſe appears, that the waters of the ſea have remained for a long track of years upon the ſurface of the earth; becauſe, in many places, ſuch immenſe banks of ſhells have been diſcovered, that it is impoſſible ſo great a multitude of animals could exiſt at the ſame time. This circumſtance ſeems likewiſe to prove, that, although the materials on the ſurface of the earth were then ſoft, and, of courſe, eaſily diſunited, moved, and tranſported, by the waters; yet theſe tranſportations could not be ſuddenly effected. They muſt have been gradual and ſucceſſive, as ſea-bodies are ſometimes found more than 1000 feet below the ſurface. Such a thickneſs of earth or of ſtone could not be accumulated in a ſhort period. Although it ſhould be ſuppoſed, that, at the deluge, all the ſhells were tranſported from the bottom of the ocean, and depoſited upon the dry land; yet, beſide the difficulty of eſtabliſhing this ſuppoſition, it is clear, that, as ſhells are found incorporated in marble and in the rocks of the higheſt mountains, we muſt likewiſe ſuppoſe, that all theſe marbles and rocks were formed at the ſame time, and at the very inſtant when the deluge took place; and that, before this grand revolution, there were neither mountains, nor marbles, nor rocks, nor clays, nor matter of any kind, ſimilar to what we are now acquainted with, as they all, with few exceptions, contain ſhells,

and

and other productions of the ocean. Besides, at the time of the universal deluge, the earth must have acquired a considerable degree of solidity, by the action of gravity for more than sixteen centuries. During the short time the deluge lasted, therefore, it is impossible that the waters should have overturned and dissolved the whole surface of the earth, to the greatest depths that mankind have been able to penetrate.

But, not to insist longer on this point, which shall afterwards be more fully canvassed, I shall confine myself to known and established facts. It is certain, that the waters of the sea have, at some period or other, remained for a succession of ages upon what we now know to be dry land; and, consequently, that the vast continents of Asia, Europe, Africa, and America, were then the bottom of an immense ocean, replete with every thing which the present ocean produces. It is likewise certain, that the different strata of the earth are horizontal, and parallel to each other*. This parallel situation must, therefore, be owing to the operation of the waters, which have gradually accumulated the different materials, and given them the same position that water itself invariably assumes. The horizontal position of strata is almost universal: In plains, the strata are exactly horizontal. It is only in the mountains that they are inclined to the horizon; because they have ori-

* Proofs, art. VII.

ginally been formed by ſediments depoſited upon an inclined baſe. Now, I maintain, that theſe ſtrata muſt have been gradually formed, and that they are not the effect of any ſudden revolution; becauſe nothing is more frequent than ſtrata compoſed of heavy materials placed above light ones, which never could have happened, if, according to ſome authors, the whole had been blended and diſſolved by the deluge, and afterwards precipitated. On this ſuppoſition every thing ſhould have had a different aſpect from what now appears. The heavieſt bodies ſhould have deſcended firſt, and every ſtratum ſhould have had a ſituation correſponding to its ſpecific gravity. In this caſe we ſhould not have ſeen ſolid rocks or metals placed above light ſand, nor clay under coal.

Another circumſtance demands our attention. No cauſe but the motion and ſediments of water could poſſibly produce the regular poſition of the various ſtrata of which the ſuperficial part of this earth is compoſed. The higheſt mountains conſiſt of parallel ſtrata, as well as the loweſt valleys. Of courſe, the formation of mountains cannot be imputed to the ſhocks of earthquakes, or to the eruptions of volcano's. Such ſmall eminences as have been raiſed by volcano's or convulſions of the earth, inſtead of being compoſed of parallel ſtrata, are mere maſſes of weighty materials, blended together in the

utmoſt

utmoſt confuſion*. But this parallel and horizontal poſition of ſtrata muſt neceſſarily be the operation of a uniform and conſtant cauſe.

We are, therefore, authoriſed to conclude, from repeated and incontrovertible facts and obſervations, that the dry and habitable part of the earth has for a long time remained under the waters of the ſea, and muſt have undergone the ſame changes which are at preſent going on at the bottom of the ocean. To diſcover what has formerly happened to the dry land, let us examine what paſſes in the bottom of the ſea; and we ſhall ſoon be enabled to make ſome rational concluſions with regard to the external figure and internal conſtitution of the earth.

The ocean, from the creation of the ſolar ſyſtem, has been conſtantly ſubject to a regular flux and reflux. Theſe motions, which happen twice in twenty-four hours, are principally occaſioned by the action of the moon, and are greater in the equatorial regions than in other climates. The earth likewiſe performs a rapid motion round its axis, and, conſequently, has a centrifugal force, which is alſo greateſt at the equator. This laſt circumſtance, independent of actual obſervations, proves, that the earth is not a perfect ſphere, but that it muſt be more elevated under the equator than at the poles. From theſe two combined cauſes, the tides, and the motion

* Proofs, art. XVII.

of the earth, it may be fairly concluded, that, although this globe had been originally a perfect ſphere, its diurnal motion, and the ebbing and flowing of the tides, muſt neceſſarily, in a ſucceſſion of time, have elevated the equatorial parts, by gradually carrying mud, earth, ſand, ſhells, &c. from other climates, and depoſiting them at the equator*. On this ſuppoſition, the greateſt inequalities on the ſurface of the earth ought to be, and, in fact, are found, in the neighbourhood of the equator. Beſides, as the alternate motion of the tides has been conſtant and regular ſince the exiſtence of the world, is it not evident, that, at each tide, the water carries from one place to another a ſmall quantity of matter which falls to the bottom as a ſediment, and forms thoſe horizontal and parallel ſtrata that every where appear? The motion of the waters, in the flux and reflux, being always horizontal, the matter tranſported by them muſt neceſſarily take the ſame parallel direction after it is depoſited.

To this reaſoning, it may be objected, that, as the flux is equal to, and regularly ſucceeded by, the reflux, the two motions will balance each other; or, that the matter brought by the flux will be carried back by the reflux; and, conſequently, that this cauſe of the formation of ſtrata muſt be chimerical, as the bottom of the ocean can never be affected by a uniform alternate motion

* Proofs, art. XII.

of

of the waters; far leſs could this motion change its original ſtructure, by creating heights, and other inequalities.

But, in the firſt place, the alternate motion of the waters is by no means equal; for the ſea has a continual motion from eaſt to weſt: Beſides, the agitations occaſioned by the winds produce great inequalities in the tides. It will likewiſe be acknowledged, that, by every motion in the ſea, particles of earth, and other materials, muſt be carried from one place, and depoſited in another; and that theſe collections of matter muſt aſſume the form of parallel and horizontal ſtrata. Farther, a well-known fact will entirely obviate this objection. On all coaſts, where the ebbing and flowing are diſcernible*, numberleſs materials are brought in by the flux, which are not carried back by the reflux. The ſea gradually increaſes on ſome places, and recedes from others, narrowing its limits, by depoſiting earth, ſand, ſhells, &c. which naturally take a horizontal poſition. Theſe materials, when accumulated and elevated to a certain degree, gradually ſhut out the water, and remain for ever in the form of dry land.

But, to remove every doubt concerning this important point, let us examine more cloſely the practicability of a mountain's being formed at the bottom of the ſea, by the motion and ſe-

* *Proofs*, art. XIX.

diments of the water. On a high coaſt which the ſea waſhes with violence during the flow, ſome part of the earth muſt be carried off by every ſtroke of the waves. Even where the ſea is bounded by rock, it is a known fact, that the ſtone is gradually waſted by the water*; and conſequently, that ſmall particles are carried off by the retreat of every wave. Thoſe particles of earth or ſtone are neceſſarily tranſported to ſome diſtance. Whenever the agitation of the water is abated, the particles are precipitated in the form of a ſediment, and lay the foundation of a firſt ſtratum, which is either horizontal, or inclined, according to the ſituation of the ſurface upon which they fall. This ſtratum will ſoon be ſucceeded by a ſimilar one, produced by the ſame cauſe; and thus a conſiderable quantity of matter will be gradually amaſſed, and diſpoſed in parallel beds. In proceſs of time, this gradually accumulating maſs will become a mountain in the bottom of the ſea, exactly reſembling, both in external and internal ſtructure, thoſe mountains which we ſee on the dry land. If there happened to be ſhells in that part of the bottom of the ſea where we have ſuppoſed the ſediments to be depoſited, they would be covered, filled, and incorporated, with the depoſited matter, and form a part of the general maſs. Theſe ſhells would be lodged in different parts of the mountains, correſpond-

* See Shaw's travels.

ing

ing to the times they were depofited. Thofe which lay at the bottom, before the firft ftratum was formed, would occupy the loweft ftation; and thofe which were afterwards depofited, would be found in the more elevated parts.

In the fame manner, when the bottom of the fea, at particular places, is troubled by the agitation of the waters, earth, clay, fhells, and other matter, muft neceffarily be removed from thefe parts, and depofited elfewhere. For we are affured by divers, that the bottom of the fea, at the greateft depths to which they defcend *, is fo ftrongly affected by the agitation of the water, that earth, clay, and fhells, are removed to great diftances. Tranfportations of this kind muft, therefore, be conftantly going on in every part of the ocean; and the matters tranfported, after fubfiding, muft uniformly raife eminences fimilar, in every refpect, to the compofition and ftructure of our mountains. Thus the motions produced by the flux and reflux, by winds and currents, muft uniformly create inequalities in the bottom of the ocean.

Farther, we muft not imagine that thefe matters cannot be carried to great diftances, fince we daily find grain, and other productions of the Eaft and Weft Indies, arriving on our coafts †. Thefe bodies are, indeed, fpecifically lighter than water; and the other fubftances

* Boyle's works, vol 3. p. 232.

† Particularly on the coafts of Scotland and of Ireland. See Ray's Difcourfes.

 are

are ſpecifically heavier. Still, however, as they are reduced to an impalpable powder, they may be kept long ſuſpended in the water, and, of courſe, tranſported to any diſtance.

It has been conceived, that the agitation produced by the winds and tides is only ſuperficial, and affects not the bottom, eſpecially when it is very deep. But it ought to be remembered, that, whatever be the depth, the whole maſs is put in motion by the tides at the ſame time; and that, in a fluid globe, this motion would be communicated even to the centre. The power which occaſions the flux and reflux is penetrating; it acts equally upon every particle of the maſs. Hence the quantity of its force, at different depths, may be determined by calculation. Indeed, this point is ſo certain, that it admits not of diſpute.

We cannot, therefore, heſitate in pronouncing, that the tides, the winds, and every other cauſe of motion in the ſea, muſt produce heights and inequalities in its bottom; and that theſe eminences muſt uniformly be compoſed of regular ſtrata, either horizontal or inclined. Theſe heights will gradually augment; like the waves which formed them, they will mutually reſpect each other; and if the extent of the baſe be great, in a track of years they will form a vaſt chain of mountains. Whenever eminences are formed, they interrupt the uniform motion of the waters, and produce new motions, known

by

by the name of currents. Between two neighbouring heights in the bottom of the ocean, there muſt be a current*, which will follow their common direction, and, like a river, cut a channel, the angles of which will be alternately oppoſite through the whole extent of its courſe. Theſe heights muſt continually increaſe; for, during the flow, the water will depoſite its ordinary ſediment upon their ridges, and the waters which are impelled by the current will force along, from great diſtances, quantities of matter, which will ſubſide between the hills, and, at the ſame time, ſcoop out a valley with correſponding angles at their foundation. Now, by means of theſe different motions and ſediments, the bottom of the ocean, though formerly ſmooth, muſt ſoon be furrowed, and interſperſed with hills and chains of mountains, as we actually find it at preſent. The ſoft materials of which the eminences were originally compoſed, would gradually harden by their own gravity. Such of them as conſiſted of ſandy and cryſtalline particles, would produce thoſe enormous maſſes of rock and flint in which we find cryſtals and other precious ſtones. Others compoſed of ſtony particles mixed with ſhells, give riſe to thoſe beds of lime-ſtone and marble, in which vaſt quantities of ſea ſhells are ſtill found incorporated. Laſtly, all our beds of marble and chalk have derived their origin from particles of ſhells mix-

* Proofs, art. XIII.

ed with a pure earth, collected and depofited at particular places in the bottom of the fea. All thefe fubftances are difpofed in regular ftrata; they all contain heterogeneous matter, and vaft quantities of fea-bodies fituated nearly in proportion to their fpecific gravities. The lighter fhells are found in chalk; the heavier in clay and lime-ftone. Thefe fhells are uniformly filled with the matter in which they are found, whether it be ftone or earth. This is an inconteftible proof, that they have been tranfported along with the matter that fills and furrounds them, and that this matter was then in the form of an impalpable powder. In a word, all thofe fubftances, the horizontal fituation of which has arifen from the waters of the fea, invariably preferve their original pofition.

It may here be objected, that moft hills, the fummits of which confift of folid rocks, or of marble, are founded upon fmall eminences, compofed of lefs heavy materials, fuch as clay or light fand, the ftrata of which commonly extend over the neighbouring plains. If the above theory be juft, what could bring about an arrangement fo fingular fo contrary, to the laws of gravity? But this phænomenon admits of a natural and eafy explication. The waters would operate firft upon the upper ftratum either of coafts or the bottom of the fea: This upper ftratum confifts generally of clay or fand; and thefe light fubftances, being carried

off

off and depoſited previous to the more denſe and ſolid, they would of courſe form ſmall eminences, and become foundations for the more heavy particles to reſt upon. After the light ſuperficial ſubſtances were removed, the harder and more ponderous would next be ſubjected to the attrition of the water, reduced to a fine powder, and carried off and depoſited above the hillocks of ſand or clay. Theſe ſmall ſtony particles would, in a ſucceſſion of ages, form thoſe ſolid rocks which we now find on the tops of hills and mountains. As particles of ſtone are heavier than ſand or clay, it is probable that they were originally covered and preſſed by ſuperior ſtrata of conſiderable depth; but that they now occupy the higheſt ſtations, becauſe they were laſt tranſported by the waves.

To confirm this reaſoning, let us inveſtigate more minutely the ſituation of thoſe materials which compoſe the ſuperficial part of the globe, the only part of which we have any adequate knowledge. The different ſtrata of ſtones in quarries are almoſt all horizontal, or regularly inclined. Thoſe founded upon hard clay, or other ſolid matter, are evidently horizontal, eſpecially in plains. The diſpoſition of quarries, where flint or browniſh free-ſtone are found in detached portions, is indeed leſs regular. But even here the uniformity of nature is not interrupted; for the horizontal or regularly inclining poſition of the ſtrata is apparent in granite and brown

brown free-ſtone, wherever they exiſt in large connected maſſes. This poſition is univerſal, except in flint and brown free-ſtone in ſmall detached portions, ſubſtances the formation of which we ſhall demonſtrate to have been poſterior to thoſe juſt now mentioned. The ſtrata of granite, vitrifiable ſand, clays, marbles, calcareous ſtones, chalk, and marls, are always parallel or equally inclined. In theſe the original formation is eaſily diſcoverable; for the ſtrata are exactly horizontal, and very thin, being placed above each other like the leaves of a book. Beds of ſand, of ſoft and hard clay, of chalk, and of ſhells, are likewiſe either horizontal or uniformly inclined. Strata of every kind preſerve the ſame thickneſs through their whole extent, which is often many leagues, and might, by proper obſervations, be traced ſtill farther. In a word, the diſpoſition of ſtrata, as deep as mankind have hitherto penetrated, is the ſame.

Thoſe beds of ſand and gravel which are waſhed down from mountains, muſt, in ſome meaſure, be excepted from the general rule. They are ſometimes of a conſiderable extent in valleys, and are ſituated immediately under the ſoil or firſt ſtratum. In plains, they are level, like the more antient and interior ſtrata. But near the bottom, or upon the ridges of hills, they have an inclination correſponding to that of the ground upon which they have been depoſited. As theſe beds of ſand and gravel are

formed by rivers and brooks, which, eſpecially in the valleys, often change their channels, it is not ſurpriſing that ſuch beds ſhould be ſo frequent. A ſmall rivulet is ſufficient, in a courſe of time, to ſpread a bed of ſand or gravel over a very large valley. In a champaign country, ſurrounded with hills, whoſe baſes, as well as the upper ſtratum of the plain, conſiſted of a hard clay, I have often obſerved, that, above the origin of the brooks or rivers, the clay was ſituated immediately under the vegetable ſtratum; but, in the low grounds, there was a ſtratum of ſand, about a foot thick, above the clay, and extending to a great diſtance from the banks of the rivers. The ſtrata formed by rivers are not very antient; they are eaſily diſtinguiſhed by their frequent interruptions, and the inequality of their thickneſs. But the antient ſtrata uniformly preſerve the ſame dimenſions through their whole extent. Beſides, theſe modern ſtrata may be diſtinguiſhed, with certainty, by the form of the ſtones and gravel they contain, which bear evident marks of having been rolled, ſmoothed, and rounded, by the motion of water. The ſame obſervation may be made with regard to thoſe beds of turf, and corrupted vegetables, which are found in marſhy grounds, immediately below the ſoil: They have no claim to antiquity, but have derived their exiſtence from ſucceſſive accumulations of decayed trees, and other plants. The ſtrata of ſlime, or mud, which occur in many places,

places, are alſo recent productions, formed by ſtagnating waters, or the inundations of rivers. They are not ſo exactly horizontal, nor ſo uniformly inclined, as the more antient ſtrata, produced by the regular motions of the ſea. In ſtrata formed by rivers, we meet with river, but ſeldom with ſea-ſhells; and the few which occur are broken, detached, and placed without order. But, in the antient ſtrata, there are no river-ſhells; the ſea-ſhells are numerous, well preſerved, and all placed in the ſame manner, having been tranſported and depoſited at the ſame time, and by the ſame cauſe. From whence could this beautiful regularity proceed? Inſtead of regular ſtrata, why do we not find the matters compoſing the earth huddled together without order? Why are not rocks, marbles, clays, marls, &c. ſcattered promiſcuouſly, or joined by irregular or vertical ſtrata? Why are not heavy bodies uniformly found in a lower ſituation than light ones? It is eaſy to perceive, that this uniformity of nature, this ſpecies of organization, this union of different materials by parallel ſtrata, without regard to their weights, could only proceed from a cauſe equally powerful and uniform as the motions of the ſea, produced by regular winds, by the tides, &c.

Theſe cauſes act with ſuperior force under the equator than in other climates; for there the tides are higher, and the winds more uniform.

form. The moſt extenſive chains of mountains are likewiſe in the neighbourhood of the equator. The mountains of Africa and Peru are the higheſt in the world, often extending through whole continents, and ſtretching to great diſtances under the waters of the ocean. The mountains of Europe and Aſia, which extend from Spain to China, are not ſo elevated as thoſe of Africa and South America. According to the relations of voyagers, the mountains of the north are but ſmall hills, when compared with the mountains of the equatorial regions. Beſides, in the northern ſeas, there are few iſlands; but, in the Torrid Zone, they are innumerable. Now, as iſlands are only the ſummits of mountains, it is apparent, that there are more inequalities on the ſurface of the earth near the equator, than in northerly climates.

Thoſe prodigious chains of mountains which run from weſt to eaſt in the Old Continent, and from north to ſouth in the New, muſt have been formed by the general motion of the tides. But the origin of the leſs conſiderable mountains and hills muſt be aſcribed to particular motions, occaſioned by winds, currents, and other irregular agitations of the ſea: Their formation may, indeed, be owing to a combination of all theſe motions, which are capable of infinite variations; for the winds, and the ſituation of different iſlands and coaſts, conſtantly change the natural courſe of the tides, and oblige them

to

to run in every poſſible direction. It is not, therefore, ſurpriſing to ſee conſiderable eminences which have no determined direction in their courſes. But, for our preſent purpoſe, it is ſufficient to have ſhown, that mountains have not been produced by earthquakes, or other accidental cauſes, but that they are effects equally reſulting from the general laws of nature, as well as their peculiar ſtructure, and the ſituation of the materials of which they are compoſed.

But how has it happened, that this earth, which we and our anceſtors have inhabited for ages, which, from time immemorial, has been an immenſe continent, dry, compact, and removed from the reach of the water, ſhould, if formerly the bottom of an ocean, be now exalted to ſuch a height above the waters, and ſo completely ſeparated from them? Since the waters remained ſo long upon the earth, why have they now deſerted it? What accident, what cauſe, could introduce a change ſo great? Is it poſſible to conceive a cauſe poſſeſſed of power ſufficient to operate ſuch an amazing effect?

Theſe are difficult queſtions. But, as the facts are incontrovertible, the preciſe manner in which they have happened may remain a ſecret, without prejudice to the concluſions that ought to be drawn from them. A little reflection, however, will furniſh us at leaſt with plauſible ſolutions *. We daily obſerve the ſea

* See proofs, art. XIX.

gaining

gaining ground on certain coaſts, and loſing it on others. We know, that the ocean has a general and uniform motion from eaſt to weſt; that it makes violent efforts againſt the rocks and the low grounds which encircle it; that there are whole provinces which human induſtry can hardly defend from the fury of the waves; and that there are inſtances of iſlands which have but lately emerged from the waters, and of regular inundations. Hiſtory informs us of inundations and deluges of a more extenſive nature. Should not all theſe circumſtances convince us, that the ſurface of the earth has experienced very great revolutions, and that the ſea may have actually given up poſſeſſion of the greateſt part of the ground which it formerly occupied? For example, let us ſuppoſe, that the Old and New worlds were formerly but one continent, and that, by a violent earthquake, the antient Atalantis of Plato was ſunk. What would be the conſequence of ſuch a mighty revolution? The ſea would neceſſarily ruſh in from all quarters, and form what is now called the Atlantic Ocean; and vaſt continents, perhaps thoſe which we now inhabit, would, of courſe, be left dry. This great revolution might be effected by the ſudden failure of ſome immenſe cavern in the interior part of the globe, and an univerſal deluge would infallibly ſucceed. I ſhould rather incline to think, that

that ſuch a revolution would not be ſuddenly accompliſhed, but that it would require a very long period. However theſe conjectures ſtand, it is certain, that ſuch a revolution has happened, and I even believe that it happened naturally; for, if a judgment of the future is to be formed from the paſt, we have only to attend carefully to what daily paſſes before our eyes. It is a fact, eſtabliſhed by the repeated obſervation of voyagers, that the ocean has a conſtant motion from eaſt to weſt. This motion, like the trade-winds, is not only perceived between the tropics, but through the whole temperate climates, and as near the poles as navigators have been able to approach. As a neceſſary conſequence of this motion, the Pacific Ocean muſt make continual efforts againſt the coaſts of Tartary, China, and India; the Indian Ocean muſt act againſt the eaſt coaſt of Africa; and the Atlantic muſt act in a ſimilar manner againſt all the eaſtern coaſts of America. Hence the ſea muſt have gained, and will always continue to gain, on the eaſt, and to loſe on the weſt. This circumſtance alone would be ſufficient to prove the poſſibility of the change of ſea into land, and of land into ſea. If ſuch is the natural effect of the ſea's motion from eaſt to weſt, may it not reaſonably be ſuppoſed, that Aſia, and all the eaſtern continent, is the moſt antient country in the world? and that Europe, and part of Africa, eſpecially the weſt parts of theſe continents, as Britain, France, Spain, &c.

are

are countries of a more recent date? Both hiſtory and phyſics concur in eſtabliſhing this hypotheſis.

But, beſide the conſtant motion of the ſea from eaſt to weſt, other cauſes concur in producing the effect juſt mentioned. There are many lands lower than the level of the ſea, and are defended by a narrow iſthmus of rock only, or by banks of ſtill weaker materials. The action of the waters muſt gradually deſtroy theſe barriers; and, conſequently, ſuch lands muſt then become part of the ocean. Beſides, the mountains are daily diminiſhing, part of them being conſtantly carried down to the valleys by rains. It is likewiſe well known, that every little brook carries earth, and other matters, from the high grounds into the rivers, by which they are at laſt tranſported to the ocean. By theſe means the bottom of the ſea is gradually filling up, the ſurface of the earth is approaching to a level, and nothing but time is wanting for the ſea's ſucceſſively changing places with the land.

I ſpeak not here of cauſes removed beyond the ſphere of our knowledge, of thoſe convulſions of nature, the ſlighteſt effort of which would be fatal to the globe. The near approach of a comet, the abſence of the moon, or the introduction of a new planet into the ſyſtem, &c. are ſuppoſitions upon which the imagination may rove at large. Cauſes of this kind will produce any effect we chooſe. From a ſingle hy-

pothefis of this nature, a thoufand phyfical romances might be compofed, and their authors might dignify them with the title of *Theory of the Earth*. As an hiftorian, I reject thefe vain fpeculations: They depend upon mere poffibilities, which, if called into action, neceffarily imply fuch a devaftation in the univerfe, that our globe, like a fugitive particle of matter, efcapes obfervation, and is no longer worthy of our attention. But, to give confiftency to our ideas, we muft take the earth as it is, examine its different parts with minutenefs, and, by induction, judge of the future, from what at prefent exifts. We ought not to be affected by caufes which feldom act, and whofe action is always fudden and violent. Thefe have no place in the ordinary courfe of nature. But operations uniformly repeated, motions which fucceed one another without interruption, are the caufes which alone ought to be the foundation of our reafoning.

Some examples fhall be given: We fhall combine particular effects with general caufes, and give a detail of facts, which will illuftrate and explain the different alterations that the earth has undergone, whether by irruptions of the fea upon the land, or by the fea's retiring from lands which it formerly covered.

That irruption which gave rife to the Mediterranean * is undoubtedly the greateft †. The

* Proofs, art. XI. and XIX.

† Ray's Difcourfes, p. 209.; Plot. Hift. Nat. &c.

ocean

ocean runs with prodigious rapidity through a narrow paſſage between two promontories*, and then forms a vaſt ſea, which, excluſive of the Black Sea, is about ſeven times larger than the kingdom of France. The motion through the Straits of Gibraltar is contrary to the motion in every other ſtrait. The general motion of the ſea is from eaſt to weſt; but, in the Straits of Gibraltar, it is from weſt to eaſt; an inconteſtible proof, that the Mediterranean Sea is not an ancient gulf, but that it has been formed by an irruption, produced by ſome accidental cauſe, ſuch as an earthquake ſwallowing up the barrier, or a violent effort of the ocean, occaſioned by the wind, and forcing its way through the bank between the two promontories of Gibraltar and Ceuta. This opinion is ſupported by the teſtimony of the ancients †, who inform us, that there was a time when the Mediterranean had no exiſtence. It is likewiſe confirmed by natural hiſtory, and by obſervations upon the ſtrata on the oppoſite coaſts of Africa and Spain, where, as in neighbouring mountains, the beds of earth and ſtone are preciſely the ſame at equal levels.

When the ocean forced this paſſage, it ran through the Straits with much more rapidity than at preſent, and inſtantly deluged that large tract of land which formerly joined Europe to

* Phil. Tranſ. abridged, vol. 2. p. 289.

† Diodorus Siculus, Strabo.

Africa. The waters covered all the grounds which were lower than the level of the ocean; and no part of them is now to be ſeen, except the tops of ſome of the mountains, ſuch as part of Italy, Sicily, Malta, Corſica, Sardinia, Cyprus, Rhodes, and the iſlands of the Archipelago.

I have not mentioned the Black Sea as an effect of this irruption; becauſe the quantity of water it receives from the Danube, the Nieper, the Don, and other rivers, is more than ſufficient both to form and ſupport this ſea. Beſides, it runs with great rapidity through the Boſphorus into the Mediterranean *. It may even be ſuppoſed that the Black and Caſpian Seas were only two large lakes, which were perhaps joined by a narrow communication, or rather by a moraſs, or ſmall lake, uniting the Don and the Wolga about Tria, where theſe two rivers run very near each other. It is likewiſe probable, that theſe two ſeas, or lakes, were formerly of a much greater extent; for the large rivers which fall into the Black and Caſpian Seas muſt have gradually brought down a quantity of earth and ſand ſufficient to ſtop up the communication, and to form that neck of land by which theſe two ſeas are divided. We know, that large rivers, in a courſe of time, block up ſeas, and form new lands, as in the province at the mouth of the Yellow River in China; Louiſiana at the

* Phil. Tranſ. abridged, vol. 2. p. 289.

mouth

mouth of the Miſſiſippi; and the northern part of Egypt, which derived its exiſtence * from the inundations of the Nile †. Such quantities of earth are brought down, by the rapidity of the Nile, from the interior parts of Africa, and depoſited during the inundations, that you may dig fifty feet deep before you can reach the bottom of the ſlime and mud. Louiſiana, and the province of the Yellow River, have, in the ſame manner, been originally formed by the ſlime of rivers.

Farther, the Caſpian Sea is a real lake. It has no communication with any other ſea, not even with the Lake Aral, which appears to have been a part of it, being only ſeparated by a large tract of ſand, in which neither river nor canal for carrying off the waters have been diſcovered. This ſea, therefore, has no external communication with any other; and I doubt much if there is any reaſon to ſuſpect a ſubterraneous communication with the Black Sea, or with the Gulf of Perſia. The Caſpian, it is true, receives the Wolga, and ſeveral other rivers, which appear to furniſh as much water as is loſt by evaporation. But, independent of the difficulties attending ſuch calculations, if it communicates with any other ſea, a uniform and rapid current towards the place of communication would be an infallible conſequence; but nothing of this kind has yet been diſcovered. Travellers of the beſt

* Shaw's Travels. † Proofs, art. XIX.

credit aſſure us of the contrary. We, therefore, conclude, that the Caſpian Sea receives juſt as much water from the rivers and clouds as it loſes by evaporation.

It is not improbable, that the Black Sea will, in time, be entirely divided from the Mediterranean; and that the Boſphorus will be choked up, whenever the rivers ſhall have accumulated a ſufficient quantity of materials to bring about that effect. It is impoſſible to fix the æra of this event; but time, and the diminution of waters in rivers, in proportion as the mountains are lowered by the cauſes mentioned above, will one day exhibit this phænomenon to the world.

The Caſpian and Black Seas ſhould, therefore, be conſidered rather as lakes than as gulfs of the ocean; becauſe they exactly reſemble other lakes which receive a number of rivers without any viſible outlet, as the Dead Sea, ſeveral lakes in Africa, and elſewhere. Beſides, the ſaltneſs of theſe two ſeas is not nearly equal to that of the Mediterranean or of the ocean; and, it is an agreed point, that the navigation in the Caſpian and Black Seas, on account of their numberleſs ſhoals, rocks, and banks, is ſo extremely hazardous, that ſmall veſſels only can be uſed in them with ſafety. This circumſtance farther proves, that theſe ſeas ought not to be conſidered as gulfs of the ocean, but as vaſt collections of water amaſſed by large rivers.

If

If the iſthmus which ſeparates Africa from Aſia were cut, it would neceſſarily create a great irruption of the ſea upon the land. This junction was formerly projected by the Kings of Egypt, and adopted ſince by the Califs. I doubt whether the pretended communication between the Red Sea and Mediterranean be ſufficiently eſtabliſhed. The Red Sea is a narrow branch of the ocean: Through its whole extent, not a ſingle river runs into it from the Egyptian ſide, and very few from the oppoſite. This ſea will not, therefore, be ſubject to diminution, like thoſe ſeas or lakes which are actually impaired by the ſlime and ſand brought down by large rivers. The Red Sea receives all its waters directly from the ocean, and the motion of the tides in it are very diſcernible; of courſe, it muſt be affected by the general motions of the ocean. The Mediterranean, on the other hand, muſt be lower than the ocean; becauſe the current through the Straits is exceedingly rapid. Beſides, it receives the Nile, which runs parallel to the weſt coaſt of the Red Sea, and paſſes through the longeſt extent of Egypt, which is a very low country. From theſe circumſtances, it is at leaſt probable, that the Red Sea is higher than the Mediterranean, and, conſequently, that, if the iſthmus of Suez were cut, a great inundation, and a conſiderable augmentation of the Mediterranean, would enſue; eſpecially if the waters were not reſtrained by dikes and ſluices, placed

at proper diſtances. This precaution was probably uſed, if ever the ancient canal ſubſiſted.

But, not to ſpend time on conjectures, which, however well founded, may perhaps appear raſh, we ſhall give ſome certain and recent examples of the changes of ſea into land, and of land into ſea *. At Venice, the bottom of the ſea is conſtantly riſing: If the canals had not been carefully kept clean, the moats and city would, long ere now, have formed a part of the continent. The ſame thing may be ſaid of moſt harbours, bays, and mouths of rivers. In Holland, the bottom of the ſea is elevated in many places; the gulf of Zuderzee and the ſtraits of the Texel cannot receive ſuch large veſſels as formerly. At the mouth of almoſt every river, we find ſmall iſlands, and banks of earth and ſand brought down from the higher grounds; and it is incontrovertible, that the ſea is conſtantly dammed up, wherever great rivers empty themſelves. The Rhine is loſt in the ſands which itſelf has accumulated. The Danube, the Nile, and all large rivers, after having tranſported great quantities of ſlime, ſand, &c. never more arrive at the ſea by a ſingle channel; they ſplit into branches, the intervals of which conſiſt of the materials which they themſelves have tranſported. Marſhes are daily drained; lands, abandoned by the ſea, are now plowed and ſown; we navigate whole countries now covered by the

* Proofs, art. XIX.

waters;

waters; in a word, we ſee ſo many inſtances of land changed into water, and water into land, that we muſt be convinced of the continual, though ſlow, progreſs of ſuch changes in all places. Hence the gulfs of the ocean will in time become continents; the iſthmuſes will be changed into ſtraits; and the tops of the mountains will be metamorphoſed into ſhoaly rocks in the ſea.

The waters, therefore, have covered, and may ill cover, every part of the earth which is now dry. Hence our aſtoniſhment at finding the productions of the ſea diſperſed every where, and a compoſition of bodies, which could not be effected by any other means than the operation of the waters, ought for ever to ceaſe. We have already explained how the horizontal ſtrata of the earth were formed. But thoſe perpendicular fiſſures, which are equally diffuſed through rocks, clays, and every conſtituent material of the globe, remain to be conſidered. The perpendicular fiſſures are indeed placed at greater diſtances from each other than the horizontal; and the ſofter the matter, the more diſtant are the fiſſures. In marble and hard ſtone, the perpendicular fiſſures are only a few feet aſunder. If the maſs of rock be extenſive, the diſtance betwixt the fiſſures is ſome fathoms: Sometimes they extend from the ſummit to the baſe of the rock, and ſometimes they terminate after arriving at a horizontal fiſſure. They are uniformly perpendicular in the

ſtrata of all calcareous ſubſtances, as chalk, marls, marble, &c. But they are more oblique, and leſs regularly ſituated, in vitreſcent bodies, brown free-ſtone, and rocks of flint, where they are often adorned with cryſtals and other minerals. In quarries of marble, or of calcareous ſtone, the fiſſures are filled with ſpar, gypſum, gravel, and an earthy ſand, which contains a conſiderable portion of chalk. In marls, and every other ſpecies of earth, except ſand-ſtone, the perpendicular fiſſures are either empty, or filled with ſuch matters as have been tranſported thither by water.

The cauſe of perpendicular fiſſures is eaſily inveſtigated. As the various materials which conſtitute the different ſtrata were tranſported by the waters, and depoſited in the form of ſediments, they would at firſt be in a very diluted ſtate, and would gradually harden and part with the ſuperfluous quantity of water they contained. In the proceſs of drying, they would naturally contract, and of courſe ſplit at irregular diſtances. Theſe fiſſures neceſſarily aſſumed a perpendicular direction; becauſe, in this direction, the action of gravity of one particle upon another is equal to nothing; but it acts directly oppoſite in a horizontal ſituation: The diminution in bulk could have no ſenſible effect but in a vertical line. I ſay, the contraction of the parts in drying, not the contained water forcing an iſſue, as has been alleged, is the cauſe of

of perpendicular fiſſures; for I have often remarked, that the ſides of theſe fiſſures, through their whole extent, correſpond as exactly as the two ſides of a ſplit piece of wood. Their ſurfaces are rude and irregular. But, if they had taken their riſe from the motion of water, they would have been ſmooth and poliſhed. Hence theſe fiſſures muſt have been produced, either ſuddenly or gradually, by drying and contracting, like the cracks and fiſſures in green wood; and the greateſt part of the water the bodies contained muſt have evaporated through the pores. In the chapter upon minerals, we ſhall demonſtrate, that ſome part of the original water ſtill remains in ſtones and ſeveral other ſubſtances; and that cryſtals, minerals, and ſome other bodies, owe their exiſtence to this water.

Perpendicular fiſſures vary greatly as to the extent of their openings. Some are about half an inch, or an inch, others a foot, or two feet; ſome extend ſeveral fathoms, and give riſe to thoſe vaſt precipices which ſo frequently occur between oppoſite parts of the ſame rocks in the Alps and other high mountains. It is plain, that the fiſſures, the openings of which are ſmall, have been occaſioned ſolely by drying. But thoſe which extend ſeveral feet are partly owing to another cauſe; namely, the ſinking of the foundation upon one ſide, while that of the other remained firm. If the baſe ſinks but a line or two, when the height of the rock is conſider-

able.

able an opening of ſeveral feet, or even fathoms, will be the conſequence. When rocks are founded on clay or ſand, they ſometimes ſlip a little to a ſide; and the fiſſures are of courſe augmented by this motion. I have not hitherto mentioned thoſe large openings, thoſe prodigious cuts, which are to be met with in rocks and mountains: Theſe could not be produced by any other means than the ſinking of immenſe ſubterraneous caverns which were unable longer to ſuſtain their incumbent load. But theſe cuts or intervals in mountains are not of the ſame nature with perpendicular fiſſures: They appear to have been ports opened by the hand of nature for the communication of nations. This ſeems to be the intention of all large openings in chains of mountains, and of thoſe ſtraits by which different parts of the ocean are connected; as the Straits of Thermopylae, of Gibraltar, &c.; the gaps or ports in Mount Caucaſus, the Cordeliers, &c. A ſimple ſeparation, by the drying of the matter, could not produce this effect: Large portions of earth muſt have been ſunk, ſwallowed up, or thrown down*.

Theſe great ſinkings, though occaſioned by accidental and ſecondary cauſes†, are leading facts in the hiſtory of the earth, and have contributed greatly in changing the appearance of its ſurface. Moſt of them have been produced by ſubterraneous fires, the exploſions of which

* Proofs, art XVII. † Ibid.

give

give riſe to earthquakes and volcano's. The force of inflamed matter, ſhut up in the bowels of the earth, is irreſiſtible *. By the action of ſubterraneous fires, whole cities have been ſwallowed up, mountains, and large tracts of country, have been overturned and rendered unfit for the habitation of men. But, though this force be great, though its effects appear to be prodigious, we cannot aſſent to the opinions of ſome authors, who ſuppoſe that theſe ſubterraneous fires are only branches of an immenſe abyſs of flame in the centre of the earth. Neither do we credit the common notion, that theſe fires have their ſeat at a great depth below the ſurface; for matter cannot begin to burn, or at leaſt the inflammation cannot be ſupported, without air. In examining the materials which iſſue from volcano's, even in their moſt violent eruptions, it is eaſy to perceive that the furnace is not very deep, and that the inflamed ſubſtances are the ſame with thoſe on the top of the mountain, only disfigured by calcination and the melting of the metallic particles they contain. To be convinced that the matters thrown out by volcano's come not from any conſiderable depth, we need only attend to the height of the mountain, and conſider the immenſe force which would be neceſſary to project ſtones and minerals to the height of half a league; for Ætna,

* Agricola de rebus quæ effluunt e terra. Phil. Tranſ. abrid. vol. ii. p. 391. Ray's Diſcourſes, p. 272.

Hecla,

Hecla, and other volcano's, have at leaſt that elevation.

Now, it is well known that fire acts equally on all ſides; it cannot, therefore, act upwards with a force ſufficient to throw large ſtones half a league high, without an equal re-action on the baſe and ſides. But the ſides of the mountain would very ſoon be pierced and blown to pieces by this re-action; becauſe the materials of which it conſiſts are not more denſe or firm than thoſe which are projected. How, then, can it be imagined, that the cavity, which muſt be conſidered as the tube or cannon, could poſſibly reſiſt a force neceſſary to raiſe ſuch heavy bodies to the mouth of the volcano? Beſides, ſuppoſe the cavity deeper, as the external orifice is not great, it would be impoſſible for ſo large a quantity of liquid and burning matters to iſſue forth at a time, without claſhing againſt each other, and againſt the irregular ſides of the cavity; and, in paſſing through ſo long a ſpace, they would be in danger of cooling and congealing. Rivers of melted ſulphur and bitumen, projected from volcano's along with ſtones and minerals, run from the tops of the mountains into the plains. Is it natural to think, that matter ſo fluid, ſo little able to reſiſt violent action, could be projected from a very great depth? Every obſervation which can be made on this ſubject will tend to prove, that the fire in volcano's is not very diſtant from the tops of

the mountains, and never descends so low as the level of the plains *.

This account of volcano's, however, is not inconsistent with their being the cause of considerable earthquakes; neither does it contradict the communication of one volcano with another, by means of subterraneous passages †. But the depth of the furnace is the object of our present investigation; and it cannot be very distant from the mouth of the volcano. To produce an earthquake, in a plain, it is not necessary that the bottom of the volcano should be below the level of that plain, nor that there should be subterraneous cavities filled with the same burning matter under the plain. A violent explosion, with which eruptions are uniformly accompanied, may, like that of a powder-magazine, give such a concussion as to produce, by its re-action, an earthquake of considerable extent.

I mean not to say that there are no earthquakes which derive their existence from subterranean fires ‡; but that there are earthquakes produced solely by the explosion of volcano's. In confirmation of what has been said upon this subject, volcano's seldom or never appear in plains; on the contrary, their mouths, or craters, are always found on the tops of the highest mountains. If the subterraneous fire of

* Borelli de incendiis Ætnæ. † Phil. Transf. abridged, vol. ii. p. 392. ‡ Proofs, art. XVI.

volcano's ſtretched below the plains, would not new paſſages be opened there during violent eruptions, rather than in the tops of the mountains, where the reſiſtance is greater? In the firſt eruption, would it not have been eaſier to pierce a plain, than a mountain of half a league in height?

It is not difficult to diſcover the reaſon why volcano's appear only in mountains. Greater quantities of minerals, ſulphur, and pyrites, exiſt in mountains, and nearer the ſurface, than in plains. The mountains have likewiſe this farther advantage; they are more ſubject to the impreſſions of the air, and receive more rain and moiſture, by which mineral ſubſtances are capable of being fermented to ſuch a degree as to produce actual inflammation.

To conclude, it has often been obſerved, that, after violent eruptions, the mountains have ſunk and diminiſhed, nearly in proportion to the quantity of matter thrown out, which is another proof that volcano's are not ſo deep as the baſe of the mountains, and even that they are not much below the ſummit.

In many places, earthquakes have formed conſiderable hollows, and even ſome large gaps, in mountains. All other inequalities are coeval with the mountains themſelves, and owe their exiſtence to currents in the ocean; for, in every place which has not been diſturbed by accidental convulſions, the ſtrata of mountains are parallel

rallel, and their angles correfpond *. It is not difficult to diftinguifh fubterraneous caverns and excavations formed by volcano's, from thofe produced by water. The latter confift only of folid rocks, the fand and clay with which they were formerly filled being carried off by the water, which is the origin of caverns in hills; for thofe found in plains are commonly nothing but old pits and quarries, like the falt-quarries of Maeftricht, the mines of Poland, &c. But natural caverns are proper to the mountains; the fummit, or higher parts, furnifh them with water, which afterwards iffues out to the furface wherever it can find a paffage. Thefe caverns are the fources of fprings and rivers. When a large cavern of this kind is fuddenly filled up by the falling of its roof, an inundation is generally the confequence †.

From thefe facts, it is eafy to perceive how much fubterraneous fires have contributed to change both the furface and internal part of the globe. This caufe has power fufficient to produce very great effects. But it is difficult to conceive how any fenfible alterations upon the land can be introduced by the winds ‡. Their dominion would appear to be confined to the fea. Indeed, next to the tides, nothing has fuch a powerful influence upon the waters; the flux and reflux proceed with an uniform pace; their

* Proofs, art. XVII. † Phil. Tranf. abridged, vol. ii. p. 322. ‡ Proofs, art. XV.

operations are always the ſame; but the action of the winds is capricious and violent. They ruſh on with irreſiſtible fury, and excite ſuch impetuous commotions, that the ocean, from a ſmooth and tranquil plain, in an inſtant is furrowed with waves which emulate the height of mountains, and daſh themſelves in pieces againſt the ſhores. The ſurface of the ocean is ſubject to conſtant alterations from the winds. But ought not the ſurface of the land, which has ſo ſolid an appearance, ever to remain uninfluenced by a cauſe of this kind? It is conſonant to experience, however, that the winds raiſe mountains of ſand in Arabia and Africa; that they overwhelm large plains with it; and that they frequently carry theſe ſands many leagues into the ſea, where they accumulate in ſuch quantities as to form banks, downs, and even iſlands*. It is alſo well known, that hurricanes are the ſcourge of the Antilles, of Madagaſcar, and of other countries, where their impetuoſity is ſo great, that they ſweep away trees, plants, and animals, together with the ſoil which nouriſhed them. They drive back, they annihilate, rivers, and produce new ones; they overthrow rocks and mountains; they ſcoop out holes and gulfs in the earth, and totally change the face of thoſe unhappy countries which give birth to them. Happily, few climates are expoſed to

* Bellarmin. de aſcen. mentis in Deum. Varen. Geog. p. 282. Voyag. de Pyrard, tom. i. p. 470.

the

the violence of thofe dreadful agitations of the air.

But the greateft changes upon the furface of the earth are occafioned by rains, rivers, and torrents from the mountains. Thefe derive their origin from vapours raifed by the fun from the furface of the ocean, and are tranfported by the winds through every climate. The progrefs of thefe vapours, which are fupported by the air, and tranfported at the pleafure of the winds, is interrupted by the tops of the mountains, where they accumulate into clouds, and fall down in the form of rain, dew, or fnow. At firft, thefe waters defcended into the plains without any fixed courfe *; but they gradually hollowed out proper channels for themfelves. By the power of gravity, they ran to the bottom of the mountains, and, penetrating or diffolving the lower grounds, they carried along with them fand and gravel, cut deep furrows in the plains, and thus opened paffages to the fea, which always receives as much water by rivers as it lofes by evaporation. The windings in the channels of rivers have uniformly correfponding angles on their oppofite banks; and as mountains and hills, which may be regarded as the banks of the valleys by which they are feparated, have likewife finuofities with correfponding angles, this circumftance feems to demonftrate, that the valleys have been gradually formed by currents of the

* See proofs, art. X. and XVIII.

 ocean,

ocean, in the ſame manner as the channels of rivers have been produced.

The waters which run upon the ſurface, and ſupport the verdure and fertility of the ſoil, compoſe not perhaps one half of the quantity that is produced by vapour. Numberleſs veins of water ſink deep into the bowels of the earth. In ſome places, you are certain of obtaining water by digging; in others, none can be found. In almoſt all the valleys and low grounds, at a certain depth, water is uniformly to be met with. But, in all high grounds, it is impoſſible to extract water from the bowels of the earth. It muſt be collected from the heavens. There are extenſive countries where no wells can be obtained: There men, and other animals, are ſupplied with drink from ciſterns and pools. In the eaſt, and eſpecially in Arabia, Egypt, and Perſia, wells and ſprings are great and valuable rarities. To ſupply their place, the inhabitants have been obliged to make large reſervoirs to collect the water that falls from the heavens. Theſe works, projected and executed from public neceſſity, conſtitute the moſt beautiful and magnificent monuments of the eaſt. Some eaſtern reſervoirs have more than two ſquare leagues of ſuperficies, and fertilize whole provinces by numberleſs ducts and canals let out from all ſides. But, in plain countries, furniſhed with large rivers, it is impoſſible to break the ſurface of the earth without finding water. In camps ſituated in the

the neighbourhood of rivers, it often happens that every tent may have its own well, by giving a few ſtrokes with a pick-ax.

Moſt of the water, ſo liberally diffuſed through low grounds, comes from the neighbouring hills and eminences. During great rains, or the ſudden melting of ſnow, part of the water runs upon the ſurface; but moſt of it penetrates the earth and rocks, by means of ſmall chinks and fiſſures. This water riſes again to the ſurface, whenever it can find an iſſue; but it often drills through ſands, and creeps along till it finds a bottom of clay, or hard earth, and there forms ſubterraneous lakes, brooks, and perhaps rivers, of which the channels are for ever buried in oblivion. Subterraneous rivers, however, muſt follow the general law of nature, and uniformly run from the higher to the lower ground. Their waters muſt of courſe either fall at laſt into the ſea, or be collected in ſome low place, whether at the ſurface or in the bowels of the earth: For there are ſeveral lakes which neither receive nor give riſe to any river. A ſtill greater number receive no conſiderable river, but are the ſources of the largeſt rivers on earth; as the lakes from which the river St. Lawrence iſſues; the lake Chiamè, from which two large rivers ariſe, that water the kingdoms of Aſem and Pegu; the lakes of Aſſiniboil in America; thoſe of Ozera in Muſcovy; thoſe that give riſe to

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the Bog and the Irtis, and many others*. It is plain, that theſe lakes muſt derive their exiſtence from the waters of ſuperior grounds, running through ſubterraneous paſſages. Some, indeed, have affirmed, that lakes are to be met with on the tops of the higheſt mountains. But this is incredible; for the lakes found on the Alps, and other elevated ſituations, are all overtopped by higher mountains, and derive their origin from the waters which run down the ſides, or are filtered through the bowels of theſe ſuperior eminences, in the ſame manner as the lakes in valleys are ſupplied.

From this reaſoning, the exiſtence of ſubterraneous collections of water, eſpecially under large plains, is apparent†: For mountains, hills, and heights of every kind, are expoſed on all ſides to the weather. The waters which fall upon their ſummits, and upon elevated plains, after penetrating the earth, muſt, from the declivity of the ground, break out at many places in the form of ſprings and fountains: Of courſe, little water will be found in the bowels of mountains. But, in plains, as the water filtrated through the earth can find no iſſue, it muſt be collected in ſubterraneous caverns, or diſperſed in ſmall veins, among ſand and gravel. This is the origin of the water ſo univerſally diffuſed through low grounds. The bottom of a pit, or well, is only a ſmall artificial baſon, into which

* Proofs, art. XI. † Proofs, art. XVIII.

the water insinuates itself from the higher grounds. At first it generally falls in by drops; but afterwards, when the passages become more open, it receives fresh supplies from greater distances, and runs in small continued veins or rills. To this circumstance it is owing, that although water may be found in any part of a plain, only a certain number of wells can be supplied. This number is in proportion to the quantity of water diffused, or rather to the extent of the higher grounds from which it comes.

To find water, it is unnecessary to dig below the level of a river. It is commonly found at smaller depths. The water of rivers seldom spreads far in the earth by filtration. Even what is found in the earth, below the level of rivers, is not derived from them; for, in rivers which have been dried up, or whose courses have been changed, no greater quantity of water is obtained by digging, than in the neighbouring ground at an equal depth. Five or six feet of earth is sufficient to contain water, and to prevent its escape: I have often remarked, that the banks of rivulets or pools have no sensible moisture at the distance of six inches from the water. It is true, the filtration is always in proportion to the penetrability of the ground. But, upon examining the stagnating pools with a sandy bottom, it is remarkable that the moisture spreads but a few inches. Neither is the extent of it great in a vegetable soil, which is

much more loose and porous than sand or hard earth. A garden-bed, though plentifully watered, communicates little or no moisture to those adjoining. I have examined level heaps of garden-earth, of six or eight feet thick, which had remained undisturbed for some years, and found that the rain-water had never reached above three or four feet deep. I have made the same observation upon earth which had lain 200 years in ridges: Below the depth of three or four feet, it was as dry as dust. Hence the spreading of water, by filtration alone, is not so extensive as has generally been imagined. Very little can descend in this way to the bowels of the earth. But water, by its own gravity, descends from the surface to the greatest depths. It sinks through natural conduits, or forces passages for itself: It follows the roots of trees, the fissures of rocks, or interstices in the earth. It divides and expands on all hands into an infinite number of small branches or rills; and uniformly descends till its progress is stopped by clay or a solid earth, where it accumulates and breaks out to the surface in form of a spring or fountain.

It would be no easy task to make an exact calculation of the quantity of subterraneous waters which have no apparent issue*. Many authors pretend that it greatly surpasses all the waters on the surface: Not to mention those who think that the interior part of the globe is en-

* Proofs, art. X. XI. and XVIII.

tirely

tirely filled with water, it is imagined by ſome, that there is an infinite number of rivers, rills, and lakes, in the bowels of the earth. But this opinion ſeems to have no proper foundation; and it is probable, that the quantity of ſubterraneous waters, which never appear at the ſurface, is very inconſiderable; for, if the number of ſubterraneous rivers were ſo great, Why do we never ſee any of their mouths break out, like ſprings, on the ſurface? Beſides, rivers produce conſiderable changes on the ſurface of the earth; they carry off the ſoil; they wear away the moſt ſolid rocks, and remove every thing that oppoſes their paſſage. The ſame effects would reſult from ſubterraneous rivers. But no ſuch changes have ever been diſcovered; nothing below the ſurface is diſplaced; the different ſtrata every where preſerve their parallel and primitive poſition; and it is only in very few places that ſubterraneous veins of water, of any conſideration, have been diſcovered. Thus, the internal operation of water is not great; but, as it is divided into an infinity of ſmall veins, which are often ſhut up by numberleſs obſtacles, it gives riſe to many ſubſtances, which are totally different, both in form and ſtructure, from thoſe of the primitive matter.

From what has been advanced, we may conclude, that the flux and reflux of the ocean have produced all the mountains, valleys, and other inequalities on the ſurface of the earth; that

currents

currents of the ſea have ſcooped out the valleys, elevated the hills, and beſtowed on them their correſponding directions; that the ſame waters of the ocean, by tranſporting and depoſiting earth, &c. have given riſe to the parallel ſtrata; that the waters from the heavens gradually deſtroy the effects of the ſea, by continually diminiſhing the height of the mountains, filling up the valleys, and choaking the mouths of rivers; and, by reducing every thing to its former level, they will, in time, reſtore the earth to the ſea, which, by its natural operations, will again create new continents, interſperſed with mountains and valleys, every way ſimilar to thoſe which we now inhabit.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE I.

Of the Formation of Planets.

AS natural hiſtory is our proper ſubject, we would willingly diſpenſe with aſtronomical obſervations. But, as the earth is ſo nearly related to the heavenly bodies, and, as obſervations of this kind illuſtrate more fully thoſe doctrines we have already advanced, it is neceſſary to give ſome general ideas concerning the formation, motion, and figure, of the earth, and other planets.

The earth is a globe of about 3000 leagues in diameter; it is ſituated 30 million of leagues from the ſun, round which it revolves in 365 days. This annual revolution is the effect of two forces; the one may be conſidered as an impulſe from right to left, or from left to right;

the other as an attraction from above downwards, or from below upwards, to a common centre. The direction and quantity of theſe forces are combined, and ſo nicely adjuſted, that they produce a uniform motion in an ellipſe approaching to a circle. Like the other planets, the earth is opaque, throws out a ſhadow, and reflects the rays of the ſun, about which it revolves in a time proportioned to its relative diſtance and denſity. It likewiſe revolves about its own axis in 24 hours; and its axis is inclined to the plane of its orbit 66½ degrees. Its figure is that of a ſpheroid, the two axes of which differ from each other about an 165th part; and it revolves round the ſhorteſt axis.

Theſe are the principal phænomena of the earth, the reſults of diſcoveries made by means of geometry, aſtronomy, and navigation. It is unneceſſary here to enumerate the proofs and obſervations by which theſe facts have been eſtabliſhed. We ſhall confine our remarks to ſuch objects as are ſtill doubtful; and ſhall therefore proceed to give our ideas concerning the formation of planets, and the changes they have undergone, previous to their arriving at the ſtate in which we now perceive them. To the many ſyſtems and hypotheſes which have been framed concerning the formation of the earth, and the different ſtates it has paſſed through, we may be allowed to add our own conjectures, eſpecially as we are determined to ſupport them with a

ſuperior

ſuperior degree of probability; and we are the more encouraged to deliver our notions on this ſubject, becauſe we hope to enable the reader to diſtinguiſh between an hypotheſis which conſiſts only of poſſibilities, and a theory ſupported by facts; between a ſyſtem, ſuch as we are about to give, of the formation and primitive ſtate of the earth, and a phyſical hiſtory of its real condition, which has been delivered in the preceding diſcourſe.

Galileo traced the laws of falling bodies; and Kepler obſerved, that the areas which the principal planets deſcribe in moving round the ſun, and thoſe of the ſatellites round their principal planets, were proportioned to the periods of their revolutions, and that theſe periods were as the ſquare roots of the cubes of their diſtances from the ſun, or from the principal planets. Newton diſcovered that the power of gravity extended to the moon, and retained it in its orbit; that the force of gravity diminiſhed in exact proportion to the ſquares of the diſtances, and, conſequently, that the moon is attracted by the earth; that the earth, and all planets, are attracted by the ſun; and, in general, that all bodies which revolve about a centre, and deſcribe areas proportioned to the periods of their revolution, are attracted by that luminary. Gravity, therefore, is a general law of nature. The planets, comets, the ſun, the earth, are all ſubject to its laws; and it is the ſource of that harmony

mony which prevails in the universe. Nothing in physics is better established than the existence of this power in every material body. Repeated experience has confirmed the effects of its influence, and the labour and ingenuity of geometers have determined its quantity and relations.

This general law being once discovered, the effects of it would be easily explained, if the action of those bodies which produce them were not too complicated. A slight view of the solar system will convince us of the difficulties which attend this subject. The principal planets are attracted by the sun, the sun by the planets, the satellites by the principal planets, and each planet attracts all the others, and is attracted by them. All these actions and re-actions vary according to the quantities of matter and the distances, and give rise to great inequalities, and even irregularities. How are so many relations to be combined and estimated? Among such a number of objects, how is it possible to trace any individual? These difficulties, however, have been surmounted; the reasonings of theory have been confirmed by calculation; every observation has produced a new demonstration; and the systematic order of the universe is now laid open to every man who is able to distinguish truth from error.

The force of impulsion, or what is commonly called the centrifugal force, is still unknown; but

but it affects not the general theory. It is evident, that, as the attractive force continually draws all the planets towards the ſun, they would fall in a perpendicular line into that luminary, if they were not kept at a diſtance by ſome other power, forcing them to move in a ſtraight line. If, again, this impulſive force were not counteracted by that of attraction, all the planets would fly off in the tangents of their reſpective orbits. This progreſſive or impulſive force was unqueſtionably at firſt communicated to the planets by the Supreme Being. But, in phyſical ſubjects, we ought, as much as poſſible, to avoid having recourſe to ſupernatural cauſes; and, I imagine, a probable reaſon may be aſſigned for the impulſive force of the planets, which will be agreeable to the laws of mechanics, and not more ſurpriſing than many revolutions that muſt have happened in the univerſe.

The ſphere of the ſun's attraction is not limited by the orbits of the planets, but extends to an indefinite diſtance, always decreaſing according as the ſquares of the augmented diſtances. The comets, it is evident, which eſcape our ſight in the heavenly regions, are, like the planets, ſubject to the attraction of the ſun, and by it their motions are regulated. All theſe bodies, the directions of which are ſo various, move round the ſun, and deſcribe areas proportioned to their periods, the planets in ellipſes, more or leſs circular, and the comets, in narrow ellipſes of vaſt

extent.

extent. The motions, therefore, both of planets and comets, are regulated by impulsive and attractive forces continually acting upon them, and obliging them to describe curves. But it is worthy of remark, that comets run through the system in all directions; that the inclinations of the planes of their orbits are so very different, that though, like the planets, they be subject to the law of attraction, they have nothing in common with regard to their progressive or impulsive motions, but appear, in this respect, to be absolutely independent of each other. The planets, on the contrary, move round the sun in the same direction, and nearly in the same plane, the greatest inclination of their planes not exceeding $7\frac{1}{2}$ degrees. This similarity in the position and motion of the planets indicates, that their impulsive and centrifugal forces must have originated from one common cause.

May we not conjecture, that a comet falling into the body of the sun might drive off some parts from its surface, and communicate to them a violent impulsive force, which they still retain? This conjecture appears to be as well founded as that of Mr Leibnitz, which supposed the earth and planets to have formerly been suns; and his system, of which an abridgment will be given in Art. V. would have been more comprehensive, and more consonant to probability, if it had embraced the above idea. We agree with him, that this effect was produced at

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the time when God is ſaid by Moſes to have ſeparated the light from the darkneſs; for, according to Leibnitz, the light was ſeparated from the darkneſs when the planets were extinguiſhed. But, on our ſuppoſition, there was a real phyſical ſeparation; becauſe the opaque bodies of the planets were detached from the luminous matter of which the ſun is compoſed *.

This notion concerning the cauſe of the centrifugal force of the planets will appear to be leſs exceptionable, after we have collected the analogies, and eſtimated the degrees of probability by which it may be ſupported. We ſhall firſt mention, that the motion of the planets have one common direction, namely, from weſt to eaſt. By the doctrine of chances, it is eaſy to demonſtrate, that this circumſtance makes it as 64 to 1, that the planets could not at all move in the ſame direction, if their centrifugal forces had not proceeded from the ſame cauſe.

This probability will be greatly augmented, if we conſider the ſimilarity in the inclinations of the planes of their orbits, which exceed not $7\frac{1}{2}$ degrees; for, by calculations, it has been diſcovered, that it is 24 to 1 againſt any two planets being found, at the ſame time, in the moſt diſtant parts of their orbits; and, conſequently, 24^5, or 7692624 to 1, that this effect could not

* If the Count de Buffon had known, that the nucleus of the ſun was a ſolid and opaque matter, a diſcovery lately made by the ingenious Dr. Wilſon of Glaſgow, his hypotheſis would have laboured under fewer difficulties.

be produced by accident; or, what amounts to the ſame, there is this great degree of probability, that the planets have been impreſſed with one common moving force, from which they have derived this ſingular poſition. But nothing could beſtow this common centrifugal motion, except the force and direction of the bodies by which it was originally communicated. We may, therefore, conclude, that all the planets have probably received their centrifugal motion by one ſingle ſtroke. Having eſtabliſhed this degree of probability, which almoſt amounts to a certainty, I next inquire what moving bodies could produce this effect; and I can find nothing but comets capable of communicating motion to ſuch vaſt maſſes.

Upon examining the courſe of comets, it is eaſy to believe that ſome of them muſt occaſionally fall into the ſun. The comet 1680 approached ſo near, that at its perihelion, it was not more diſtant from the ſun than a ſixteenth part of his diameter; and, if it returns, which is extremely probable, in the year 2255, it may then fall into the ſun. This event muſt depend upon the accidents it meets with in its courſe, and the retardations it ſuffers in paſſing through the ſun's atmoſphere*.

We may, therefore, preſume, with the great Newton, that comets ſometimes fall into the ſun. But they may fall in different directions.

* See Newt. edit. 3. p. 525.

If they fall perpendicularly, or in a direction not very oblique, they will remain in the body of the ſun, ſerve the purpoſes of fewel, and, by their impulſe, remove the ſun from his place, in proportion to the quantity of matter they contain*. But, if a comet falls in a very oblique direction, which will moſt frequently happen, it will only graze the ſurface, or penetrate to no great depth. In this caſe, it may force its way paſt the ſun, detach certain portions of his body, to which it will communicate a common impulſive motion; and theſe portions puſhed off from the ſun, and even the comet itſelf, may turn planets, which will revolve round this luminary in the ſame direction, and nearly in the ſame plane. A calculation, perhaps, might be made of the quantity of matter, velocity, and direction, a comet ought to have, in order to force from the ſun maſſes equal to thoſe which compoſe the ſix planets and their ſatellites. But it is ſufficient here to obſerve, that the whole planets, with their ſatellites, make not a 650th part of the ſun's maſs †; for although the denſity of Saturn and Jupiter be leſs than that of the ſun, and though the earth be four times, and the moon near five times, more denſe than the ſun; yet they are only atoms when compared to his immenſe volume.

* Quær. Would not ſuch an event, by augmenting the ſun's quantity of matter, and, conſequently, his attractive power, produce other changes in the ſolar ſyſtem? † See Newt. p. 405.

It muſt be acknowledged, that, although a 650th part of a whole may ſeem inconſiderable, it would require a very large comet to detach this part from the ſun. But, if we conſider the prodigious rapidity of comets in their perihelion; the near approach they make to the ſun; the denſity and ſtrong coheſion of parts neceſſary to ſuſtain, without deſtruction, the inconceivable heat they undergo; and the ſolid and brilliant nucleus which ſhines through their dark atmoſpheres; it cannot be doubted that comets are compoſed of matters extremely denſe and ſolid; that they contain, in ſmall limits, a great quantity of matter; and, conſequently, that a comet of no enormous ſize may remove the ſun from his place, and give a projectile motion to a maſs of matter equal to the 650th part of his body. This remark correſponds with what we knew concerning the reſpective denſities of the planets, which always decreaſe in proportion to their diſtances from the ſun, having leſs force of heat to reſiſt. Accordingly, Saturn is leſs denſe than Jupiter, and Jupiter much leſs than the earth. Thus, if the denſity of the planets, as Newton alleges, be in proportion to the quantity of heat they ſupport, Mercury will be ſeven times denſer than the earth, and 28 times denſer than the ſun, and the comet 1680, 28,000 times more denſe than the earth, or 112,000 times denſer than the ſun. Now, ſuppoſing the quantity of matter in this comet to be equal to a ninth

ninth part of the ſun, or allowing it to be only 100dth part of the bulk of the earth, its quantity of matter would ſtill be equal to a 900th part of the ſun: Hence a body of this kind, which would be but a ſmall comet, might puſh off from the ſun a 900th or a 650th part, eſpecially when the amazing rapidity of comets, in their perihelion, is taken into the calculation.

The correſpondence between the denſity of the whole planets, and that of the ſun, deſerves alſo to be noticed. Upon, and near the ſurface of the earth, there are ſubſtances 1400 or 1500 times denſer than others; the denſities of air and gold are nearly in this proportion. But the interior parts of the earth and planets are more uniform, and differ little with regard to denſity; and the correſpondence in the denſity of the planets and that of the ſun is ſo great, that, out of 650 parts, which comprehend the whole denſity of the planets, there are more than 640 nearly of the ſame denſity with the ſolar matter; and there are only ten of thoſe 650 which are of a ſuperior denſity; for the denſity of Saturn and Jupiter is nearly the ſame with that of the ſun; and the quantity of matter in thoſe two planets is at leaſt 64 times greater than what is contained in the four inferior planets, Mars, the Earth, Venus, and Mercury. We may, therefore, conclude, that, in general, the matter of the planets is very nearly of the ſame

kind with the ſolar matter, and, of courſe, that the former may have been ſeparated from the latter.

To this theory it may be objected, that, if the planets had been driven off from the ſun by a comet, in place of deſcribing circles round him, they muſt, according to the law of projectiles, have returned to the ſame place from whence they had been forced? and, therefore, that the projectile force of the planets cannot be attributed to the impulſe of a comet.

I reply, that the planets iſſued not from the ſun in the form of globes, but in the form of torrents, the motion of whoſe anterior particles muſt have been accelerated by thoſe behind, and the attraction of the anterior particles would alſo accelerate the motion of the poſterior; and that this acceleration, produced by one or both of theſe cauſes, might be ſuch as would neceſſarily change the original motion ariſing from the impulſe of the comet, and that, from this cauſe, might reſult a motion ſimilar to what takes place in the planets, eſpecially when it is conſidered, that the ſhock of the comet removes the ſun out of its former ſtation. This reaſoning may be illuſtrated by an example. Suppoſe a muſket-ball diſcharged from the top of a mountain, and that the force of the powder was ſufficient o puſh it beyond a ſemidiameter of the earth, it is certain that this ball would revolve round the

the earth, and return at every revolution to the place from whence it had been difcharged. But, inftead of a mufket-ball, if a rocket were employed, the continued action of the fire would greatly accelerate the original impulfive motion. This rocket would by no means return to the fame point, like the ball; but, *cæteris paribus*, would defcribe an orbit, the perigee of which would be more or lefs diftant from the earth in proportion to the greatnefs of the change produced in its direction by the accelerating force of the fire. In the fame manner, if the original projectile force impreffed by the comet on the torrent of folar matter was accelerated, it is probable, that the planets formed by this torrent acquired their prefent circular or elliptical movements around the fun.

The appearances exhibited in great eruptions from volcano's may give fome idea of this acceleration of motion. When Vefuvius begins to groan and throw out inflamed matter, it has been often remarked, that the motion of the cloud firft ejected is flower than the fucceeding ones, and that they go on increafing in celerity, till at laft fulphur, lava, melted metal, and huge ftones are thrown up; and that, though thefe obferve nearly the fame direction, they alter confiderably that of the firft cloud, and elevate it to a greater height than it would otherwife have reached.

The objection will be ſtill farther obviated, if it is conſidered, that the impulſe of the comet muſt, in ſome degree, have communicated a motion to the ſun, and removed it from its former ſituation; and that, although this motion may now be ſo ſmall as to eſcape the notice of aſtronomers, it may ſtill, however, exiſt, and make the ſun deſcribe a curve round the centre of gravity of the ſyſtem. If this be allowed, as I preſume it will, the planets, inſtead of returning to the ſun's body, would deſcribe orbits, the perihelions of which would be as diſtant from the ſun as the ſpace that he preſently occupies is diſtant from his original ſtation.

It may be farther objected, that, if motion be accelerated in the ſame direction, no change in the perihelion could take place. But is it credible, that no change of direction can happen in a torrent whoſe particles ſucceed each other? On the contrary, it is extremely probable, that a change was actually produced ſufficient to make the planets move in their preſent orbits.

It may ſtill be objected, that, if the ſituation of the ſun had been changed by the ſhock of a comet, it would move uniformly; and, of courſe, this motion being common to the whole ſyſtem, no alteration would be effected. But, previous to the ſhock, might not the ſun move round the centre of the cometary ſyſtem; and might

not

not this primary motion be augmented or diminished by the ſtroke of the comet? Is not this ſufficient to account for the actual motion of the planets?

If none of theſe ſuppoſitions be admitted, may it not be preſumed, that the elaſticity of the ſun might elevate the torrent above his ſurface, in place of puſhing it directly forward? This circumſtance alone would be ſufficient to remove the perihelion, and endow the planets with their preſent movements. Neither is this ſuppoſition deſtitute of foundation: The ſolar matter may be exceedingly elaſtic; ſince light, the only part of it we are acquainted with, ſeems, by its effects, to be perfectly elaſtic. I acknowledge that I cannot determine which of the cauſes above aſſigned has actually produced an alteration in the projectile force of the planets; but they at leaſt ſhow that ſuch a change is not only poſſible, but probable, which is enough for my preſent purpoſe.

Without farther inſiſting on the objections which may be made againſt my hypotheſis, or the analogical proofs that might be brought in ſupport of it, I ſhall proſecute my ſubject, and draw the proper concluſions. Let us firſt examine what might happen to the planets, and particularly to the earth, when they were impreſſed with their projectile forces, and what was their ſtate after their ſeparation from the body of the

ſun. A projectile motion having been communicated, by the ſtroke of a comet, to a quantity of matter equal to a 650th part of the ſun's maſs, the light particles would ſeparate from the denſe, and, by their mutual attractions, form globes of different ſolidities. Saturn being compoſed of the largeſt and lighteſt parts, would be removed to the greateſt diſtance from the ſun; Jupiter, being denſer than Saturn, would have a nearer ſtation; and ſo of the reſt. The largeſt and leaſt ſolid planets are moſt diſtant, becauſe they received a greater projectile force than the ſmaller and denſer; for the projectile force being proportioned to the ſurface to which it is applied, the ſame ſtroke would make the larger and lighter parts of the ſolar matter move with more rapidity than the ſmaller and heavier. The parts, therefore, which differed in denſity, would ſeparate from each other in ſuch a manner, that, if the denſity of the ſolar matter be equal to 100, that of Saturn will be equal to 67, of Jupiter, = 94½, of Mars, = 200, of the Earth, = 400, of Venus, = 800, of Mercury, = 2800. But, as the attractive force acts not in proportion to the ſurface, but to the quantity of matter, it would retard the progreſs of the more denſe parts of the ſolar matter; and it is for this reaſon that we find the moſt denſe planets neareſt the ſun, and which move round him with more rapidity than thoſe that are more diſtant, and leſs denſe.

The

The denſity and projectile motion of Saturn and Jupiter, the two largeſt planets in the ſyſtem, have the moſt exact proportion. The denſity of Saturn is to that of Jupiter as 67 to $94\frac{1}{2}$, and their velocities are nearly as $88\frac{2}{3}$ to $120\frac{1}{71}$, or as 67 to $90\frac{11}{16}$. How rarely do pure conjectures correſpond ſo exactly to the phænomena of nature? It is true, according to this relation between the celerity and denſity of the planets, the denſity of the earth ought not to exceed $206\frac{7}{18}$, inſtead of 400, which is its real denſity; hence it may be ſuppoſed, that the earth has now double its original denſity. With regard to the other planets, Mars, Venus, and Mercury, as their denſities are only conjectural, we know not whether this circumſtance would confirm or weaken our hypotheſis. Newton ſays, that the denſities of the planets are proportioned to the degrees of heat they are expoſed to; and it is in conſequence of this idea that we have mentioned Mars as being one time leſs denſe than the earth, Venus one time, Mercury ſeven times, and the comet 1680, 28,000 times denſer than the earth. But, if we attend to Saturn and Jupiter, the two principal planets, we will find, that this ſuppoſed proportion between the denſities of the planets, and the heat they ſuſtain, is not well founded: For, according to this hypotheſis, the denſity of Saturn would be as $4\frac{7}{18}$, and that of Jupiter as $14\frac{17}{22}$, inſtead of the proportions of 67 and $94\frac{1}{2}$; differences ſo great as

to

to deſtroy the principles upon which they are founded. Thus, notwithſtanding the regard due to the conjectures of Newton, I cannot refrain from thinking that the denſities of the planets have a nearer relation to their celerities than to the degrees of heat to which they are expoſed. This, indeed, is only a final cauſe; but the other is a phyſical relation, the exactneſs of which is remarkable in Saturn and Jupiter. It is certain, however, that the denſity of the earth, inſtead of being $206\frac{7}{8}$, is 400; and, conſequently, the earth muſt have ſuffered a condenſation in the proportion of $206\frac{7}{8}$ to 400.

But have the condenſations of the planets no relation to the quantity of ſolar heat they ſuſtain? In that caſe, Saturn, which is at the greateſt diſtance from the ſun, would have ſuffered little or no condenſation; and Jupiter would be condenſed from $90\frac{11}{16}$ to $94\frac{1}{2}$. Now, the ſun's heat in Jupiter being to his heat in the earth as $14\frac{17}{22}$ to 400, their condenſation ought to be in the ſame proportion. Thus, if Jupiter be condenſed as $90\frac{11}{16}$ to $94\frac{1}{2}$, the earth, if it had been in the orbit of Jupiter, would have been condenſed from $206\frac{7}{8}$ to $215\frac{990}{1451}$; but the earth being much nearer the ſun, and receiving heat, in proportion to that of Jupiter, as 400 to $14\frac{17}{22}$, the quantity of condenſation it would have undergone in the orbit of Jupiter muſt be multiplied by the proportion of 400 to $14\frac{17}{22}$, which will give nearly $234\frac{1}{3}$ for the condenſa-

tion

tion the earth muſt have received. The denſity of the earth was $206\frac{7}{8}$; by adding its acquired condenſation, its actual denſity will be $400\frac{7}{8}$, which is nearly the ſame with 400, its real denſity determined by the moon's parallax. With regard to the other planets, I pretend not to give exact proportions, but only approximations, tending to ſhew, that their denſities have a ſtrong connection with the celerity of their motions in their reſpective orbits.

The comet, by falling obliquely on the ſun, as mentioned above, muſt have forced off from his ſurface a quantity of matter equal to a 650th part of his body. This matter, being in a liquid ſtate, would at firſt form a torrent, of which the largeſt and rareſt parts would fly to the greateſt diſtances; the ſmaller and more denſe, having received only an equal impulſe, would remain nearer the ſun; his power of attraction would operate upon all the parts detached from his body, and make them circulate round him; and, at the ſame time, the mutual attraction of the particles of matter would cauſe all the detached parts to aſſume the form of globes, at different diſtances from the ſun, the nearer moving with greater rapidity in their orbits than the more remote.

But it may be objected, that, if the planets had been detached from the ſun, they muſt have been burning and luminous, not cold and opaque bodies; nothing can have leſs reſemblance

femblance to a globe of fire than a globe compofed of earth and water; and, by comparifon, the matter of the earth is totally different from that of the fun.

It may be replied to this objection, that the matter changed its form after its feparation, and that the fire, or light, was extinguifhed by the projectile motion communicated by the ftroke. Befides, may it not be fuppofed, that the fun, or a burning ftar, moving with a rapidity equal to that of the planets, would foon be extinguifhed; and that this may be the reafon why all the luminous, or burning ftars, are fixed, and without motion; and why thofe called new ftars, which have probably changed their ftations, are frequently extinguifhed and difappear? To confirm this remark, comets, when in their perihelia, ought to be inflamed even to their centre; but they never become luminous ftars; they only emit a burning vapour, a confiderable portion of which they leave behind them in their courfe.

In a medium which has little refiftance, I acknowledge, that fire may fubfift, although the burning body be moved with great rapidity. It muft likewife be acknowledged, that what I have faid applies only to thofe ftars which difappear for ever, not to thofe that appear and difappear at ftated intervals, without changing their fituations in the heavens. Of thefe Maupertuis, in his difcourfe on the figure of the ftars, has given a moft fatisfactory account. But thofe which

which have appeared, and then vaniſhed for ever, muſt unqueſtionably have been extinguiſhed either by the quickneſs of their motion, or ſome other cauſe. There is not a ſingle example of a luminous ſtar revolving round another; and not one of the ſixteen planets which revolve round the ſun have any light in themſelves.

Farther, fire, in ſmall maſſes, cannot ſubſiſt ſo long as in large ones. The planets would burn a conſiderable time after they iſſued from the ſun; but, at length, would extinguiſh for want of combuſtible matter. For the ſame reaſon, the ſun itſelf will be extinguiſhed; but at a period as much beyond that which extinguiſhed the planets, as the quantity of matter in the ſun exceeds that of the planets. However this may be, the ſeparation of the planets from the ſun, by the ſhock of a comet, appears ſufficient to account for their extinction.

The earth and planets, when they iſſued from the ſun, were totally compoſed of liquid fire; in which ſtate they would continue no longer than the violence of the heat that kept them in fuſion. But this heat would gradually decay from the moment they left the ſun. During their fluid ſtate, they neceſſarily aſſumed circular figures; and their diurnal motion would elevate their equators, and flatten their poles. I agree with M. Leibnitz *, that this figure corre-

* Vid. Act. Erud. Lipſ. an. 1692.

ſponds

ſponds ſo exactly with the laws of hydroſtatics, that the earth and planets muſt neceſſarily have been once in a ſtate of fluidity occaſioned by fire; and, conſequently, that the interior parts of the earth muſt be compoſed of vitrified matter, of which ſand, free-ſtone, granite, and perhaps clay, are fragments, or ſcoriæ.

It is therefore extremely probable, that the planets were originally parts of the ſun ſeparated by a ſtroke which communicated to them a projectile motion; and that their different diſtances proceeded ſolely from the difference of their denſities. To complete this theory, it only remains to account for the diurnal motion of the planets, and the origin of their ſatellites; which, inſtead of adding freſh difficulties, will tend greatly to confirm my hypotheſis: For rotation, or what is called diurnal motion, entirely depends on the obliquity of the ſtroke; an oblique impulſe on the ſurface of a body neceſſarily gives it a rotatory motion. If the body which receives the impulſe be homogeneous, the rotatory motion will always be equal and uniform; but it will be unequal, if the body conſiſt of heterogeneous parts, or of parts different in denſity. Hence we may conclude, that the matter of each planet is homogeneous, becauſe the diurnal motion of each is uniformly performed in the ſame time; and this circumſtance is an additional proof, that portions of different denſities were originally ſeparated from the ſun.

But

But the obliquity of the ſtroke might be ſo great as to throw off ſmall quantities of matter from the principal planet, which would neceſſarily move in the ſame direction. Theſe parts, by mutual attraction, would reunite, according to their denſities, at different diſtances from the planet, follow its courſe round the ſun, and at the ſame time revolve about the body of the planet, nearly in the plane of its orbit. It is eaſy to perceive that the portions we mean are the ſatellites: Thus the formation, poſition, and motion, of the ſatellites correſpond, in the moſt perfect manner, with our theory; for they all move in the ſame direction, and in concentric circles round their principal planets, and nearly in the plane of their orbits. All theſe common effects, depending on an impulſive force, muſt have proceeded from a common cauſe, which was a projectile force communicated to them by the ſame oblique ſtroke. This account of the motion and formation of the ſatellites will be ſtrongly ſupported, if the other circumſtances and phænomena attending them be duly weighed. Thoſe planets which are furniſhed with ſatellites move quickeſt round their axes. The revolution of the earth is quicker than that of Mars, in the proportion nearly of 24 to 15; the earth has a ſatellite, and Mars has none; Jupiter, whoſe diurnal motion is 500 or 600 times more rapid than that of the earth, has four ſatellites; and it is extremely probable, that Saturn, who

has five ſatellites and a ring, revolves much more quickly than Jupiter.

We may even conjecture, with ſome probability, that the plane of the equator of Saturn's ring is nearly the ſame with that of the planet; for, ſuppoſing, according to the preceding theory, the obliquity of the impulſe which put Saturn in motion to have been very great, his diurnal motion would at firſt be in proportion to the exceſs of the centrifugal force above that of gravity, and, of courſe, a conſiderable quantity of matter would be thrown off from his equatorial regions, and neceſſarily aſſume the figure of a ring, the plane of which would be nearly the ſame with that of his own equator. This quantity of matter, detached from the equatorial regions of Saturn, muſt have flattened the equator of that planet; which is the reaſon why, notwithſtanding the rapidity with which we have ſuppoſed him to revolve round his axis, the diameters of Saturn are not ſo unequal as thoſe of Jupiter, which differ from each other more than an eleventh part.

Though this theory of the formation of the planets and their ſatellites appears to be extremely probable; yet, as every man has his own ſtandard of eſtimating probabilities of this nature, and as this ſtandard varies according to the different capacities of combining analogies more or leſs remote, I pretend not to convince thoſe who are unwilling to believe. I have offered theſe

ideas to the public, not only becauſe I thought them rational, and calculated to unravel a ſubject upon which, however important, nothing has hitherto been written; but becauſe the impulſive motion of the planets gives riſe to numberleſs phænomena in the univerſe, which admit not of an explanation by gravity alone. To thoſe who may be diſpoſed to deny the poſſibility of my theory, I would propoſe the following queries:

1. Is it not natural to imagine, that a moving body has received its motion from the impulſe of ſome other body?

2. When ſeveral bodies move in the ſame direction, is it not exceedingly probable, that they received this direction from a ſingle ſtroke, or, at leaſt, from ſtrokes every way ſimilar?

3. When ſeveral bodies in motion have not only the ſame direction, but are placed in the ſame plane, is it not more natural to think that they received this direction and poſition from one impulſe than from many?

4. Is it not probable, that a body put in motion by impulſe, ſhould receive it in an oblique direction; and conſequently that it ſhould be forced to move round its axis with a rapidity proportioned to the obliquity of the ſtroke? If theſe queries be not unreaſonable, the theory of which we have given a ſketch will no longer have the appearance of abſurdity.

Let us now proceed to a more interefting object; let us examine the figure of the earth upon which fo many inquiries and obfervations have been made. As it appears, from the equality of the earth's diurnal motion, and the uniformity in the inclination of its axis, that it is compofed of homogeneous parts which mutually attract each other in proportion to their quantities of matter; if its impulfive motion had been communicated in a direction perpendicular to its furface, it would neceffarily have affumed the figure of a perfect fphere: But, having been ftruck obliquely, it moved round its axis at the inftant it received its figure; and, from the combination of the projectile force and that of attraction, there refulted a fpheroid figure, more elevated at the equator than at the poles; becaufe the centrifugal force, arifing from the diurnal rotation of the earth, muft diminifh the action of gravity, or that power which makes all the parts tend to the centre. Thus the earth, being compofed of homogeneous parts, and having been endowed with a rotatory motion, muft neceffarily have affumed a fpheroidal figure, the two axes of which differ from each other by a 230th part. To fhow that this is the real figure of the earth, we need not have recourfe to hypothefes; it is capable of the cleareft demonftration. The laws of gravitation are well known: That bodies attract each other

directly

directly as their quantities of matter, and inversely as the squares of their distances, admits not of a doubt. It can as little be doubted, that the total action of any body is composed of all the particular actions of its parts.

The parts of bodies are all mutually attracted in the above proportion; and all these attractions, when the body has no rotation, necessarily produce a sphere, and a spheroid, when the body is endowed with a rotatory motion. This spheroid is more or less flattened at the poles in proportion to the quickness of the diurnal motion; and the earth, in consequence of the celerity of its rotation, and the mutual attraction of its parts, has assumed the figure of a spheroid, of which the two axes are to one another as 229 to 230.

Thus the earth, at the time of its formation, from the original constitution and homogeneity of its parts, and independent of every hypothesis derived from the direction of gravity, took the figure of a spheroid; and, from the known laws of mechanics, its equatorial diameter was necessarily elevated about six leagues and a half more than its poles.

I shall dwell the longer on this article, because there are some geometers, who, from a system of philosophy they have adopted, and from a supposed direction of gravity, still imagine that the figure of the earth depends upon theory. The first thing to be demonstrated is

the mutual attraction of the parts of matter; and the second, the homogeneity of the terrestrial globe. When these two facts are clearly proved, there will be no occasion to have recourse to any theory derived from the direction of gravity; because the earth's figure, in this case, must necessarily be as Newton determined it; and all the other figures assigned to it, in consequence of vortexes, and other hypotheses, can have no existence.

It will not be doubted, even by the most incredulous, that the planets are retained in their orbits by the power of gravity. The satellites of Saturn gravitate towards that planet; those of Jupiter towards Jupiter; the moon gravitates towards the earth; and Saturn, Jupiter, Mars, the Earth, Venus, and Mercury, gravitate towards the sun. In the same manner, Saturn, Jupiter, and the Earth, gravitate towards their respective satellites, and the sun gravitates towards the whole planets. Gravitation is therefore a general law, by which the whole planetary system is mutually affected; for action cannot exist without re-action. This mutual attraction of the planets is the law which regulates all their motions; and its existence is demonstrated by its effects. When Saturn and Jupiter are in conjunction, their mutual attraction produces an irregularity in their motion round the sun. The earth and the moon, also, mutually attract each other; but the irregularities in the moon's motion

tion proceed principally from the attraction of the ſun; and hence the ſun, the earth, and the moon, mutually act upon each other. Now, the reciprocal attraction of the planets, when the diſtances are equal, is proportioned to their quantities of matter; and the ſame power of gravity, which makes heavy bodies fall to the earth, and which extends as far as the moon, is likewiſe in proportion to the quantity of matter: The total gravity of a planet, therefore, is compoſed of the gravity of all its parts: Hence all the parts of matter, whether in the earth or planets, mutually attract each other; and, of courſe, the rotation of the earth round its axis muſt neceſſarily have beſtowed on it the figure of a ſpheroid, the axes of which are as 229 to 230. But the direction of gravity muſt be perpendicular to the earth's ſurface; and, conſequently, unleſs the general and mutual attraction of the parts of matter be denied, no hypotheſis derived from the direction of gravity can have any ſolid foundation. But this mutual attraction, as we have ſeen, is demonſtrated by actual obſervation; and the experiments made by pendulums prove its univerſal extenſion. No hypotheſis, therefore, founded on the direction of gravity, can be admitted, without contradicting both reaſon and experience.

Let us now examine whether the parts compoſing the terreſtrial globe be homogeneous. I acknowledge, that, if the globe be ſuppoſed to

consist of parts differing in density, the direction of gravity would be different from that we have assigned, and that the earth's figure would vary according to the different suppositions which might be made concerning the direction of gravity. But, why make suppositions of this kind? Why, for example, do we suppose the parts near the centre to be more dense than those more distant from it? Are not all the particles which compose the globe united by their mutual attraction? Every particle, therefore, is a centre; and there is no reason to believe that the parts which surround the centre are denser than those which surround any other point. Besides, if any considerable part of the earth were more dense than another, the axis of rotation would approach nearer that part, and create an inequality in the diurnal revolution of the globe: It would produce an inequality in the apparent motion of the fixed stars; they would appear to move more quickly or slowly in the zenith or horizon, according as we happened to be situated on the heavy or light parts of the earth; and the axis of the globe, not passing through its centre of gravity, would make a perceptible change in its position. But nothing of this kind ever takes place. On the contrary, the diurnal revolution of the earth is equal and uniform. At every point of the earth's surface, the stars appear to move with the same quickness; and, if there be any nutation in its axis, it is too inconsiderable

to

to attract obfervation. Hence it may be concluded, that all the parts of the globe are at leaft nearly homogeneous.

If the earth were hollow, the cruft of which, for example, exceeded not three leagues in thicknefs, it would give rife to the following phænomena. 1. The mountains would bear fo great a proportion to the total thicknefs of the cruft, that vaft irregularities in the earth's motion would be occafioned by the attraction of the moon and of the fun: When the moon was in the meridian of the more elevated parts, as the Cordeliers, her attraction upon the whole globe would be much greater than when fhe was in the meridian of the lower parts. 2. The comparative attraction of the mountains would be greatly increafed; and the experiments made on Mount Chimboraco, in Peru, would have given more degrees in the deviation of the plumb-line than they actually gave feconds. 3. The weight of bodies would be greater on the tops of mountains than in the plains; and men would find themfelves more weighty, and would walk with more difficulty, in high than in low grounds. Thefe obfervations, and many others which might be made, fhould convince us, that the interior parts of the earth are not hollow, but that they are compofed of matter of a confiderable denfity.

If, on the other hand, the earth, at the depth of two or three leagues, confifted of matter

much

much denser than that we are acquainted with, upon descending even into ordinary pits, we should find ourselves considerably heavier; and the motion of pendulums would there be more accelerated than they actually are when brought down from a hill to a plain. Hence we may presume that the interior parts of the earth consist of matter nearly similar to that on its surface. Of this, we will be still farther convinced, if we consider that the earth, at the time of its original formation, when it assumed its present spheroidal figure, was in a state of fusion, and, consequently, that all its parts were homogeneous, and nearly of equal density. The matter on the surface, though originally the same with that of the interior parts, has, in the revolutions of time, undergone many changes from external causes; and to these are to be ascribed the production of materials so different in their densities. But it ought to be remarked, that the densest bodies, as gold, and other metals, are most rarely to be met with; and, consequently, that the greatest quantity of materials at the surface, have suffered little alteration with regard to density. The most common materials, indeed, as sand and clay, differ so little in density, that we may conjecture, with much probability, the internal parts of the earth to consist of a vitrified matter, the density of which is nearly equal to that of sand; and, consequently, that

that the whole globe may be conſidered as one homogeneous maſs.

But, it may be ſaid, that, though the earth were compoſed of concentric beds, of different denſities, the equality of its diurnal motion, and the uniform inclination of its axis, would remain equally undiſturbed, as upon the ſuppoſition of its conſiſting wholly of homogeneous matter. This I allow; but I demand, at the ſame time, whether there be any reaſon for believing that theſe beds of different denſities really exiſt? Whether this method of ſolving difficulties be not an attempt to adjuſt the works of nature to our own imaginations? And whether ſuppoſitions, neither founded on obſervation nor analogy, ought to find admittance into phyſical reaſoning?

Hence, it is apparent, that the earth received its ſpheroidal figure in conſequence of its diurnal motion, and the mutual attraction of its parts; that this figure neceſſarily reſulted from the globe's being in a liquid ſtate; that, according to the laws of gravity and of a centrifugal force, it could not poſſibly aſſume any other figure; that, at the moment of its formation, the difference between its two diameters was, as at preſent, equal to a 230th part; and, of courſe, that all other hypotheſes which make this difference greater or leſs, are mere fictions, and deſerve no attention.

Perhaps

Perhaps it may be objected, that, if this theory be well founded, and if the proportion of the axes of the two diameters be as 229 to 230, how came the mathematicians sent to Lapland and Peru to concur in making it as 174 to 175? Why should such a difference subsist between practice and theory? And, is it not more reasonable to give the preference to actual measurement, especially when executed by the ablest mathematicians in Europe*, and furnished with all the necessary apparatus?

To this I reply, that I mean not to combat the observations made at the equator, and near the pole; that I doubt not of their exactness; and that the earth may actually be elevated a 175th part more at the equator than at the poles. Still, however, I maintain my theory; and I perceive clearly how it may be reconciled to practice. The difference between the two conclusions is about four leagues in the two axes. The equatorial regions are found to have an elevation of two leagues more than they ought to have by the theory. This height of two leagues corresponds exactly with the greatest inequalities which have been produced on the surface of the globe by the motion of the sea, and the action of fluids. Here some illustration is necessary. At the time of the earth's formation, in consequence of the mutual attraction of its parts, and of its centrifugal force, it must have assumed a

* M. de Maupertuis, figure de la terre.

spheroidal

ſpheroidal figure, with its axes different by a 230th part. This would be the real figure of the earth while it remained in a ſtate of liquefaction. But, after cooling for ſome time, the rarified vapours, like thoſe in the tail or atmoſphere of a comet, would condenſe, and fall on the ſurface in the form of air and water; and, when theſe waters begin to be agitated by a flux and reflux, ſand, and other bodies, would be gradually tranſported from the poles towards the equatorial parts. This operation, when continued for ſome time, would neceſſarily ſink the poles, and elevate the equator in the ſame proportion. The ſurface of the earth being likewiſe expoſed to the winds, to the action of the air and of the ſun; all theſe cauſes would concur with the tides in furrowing the earth, in ſcooping out valleys, in elevating the mountains, and in producing other ſuperficial irregularities, none of which, perhaps, exceed a league in thickneſs, even at the equator. This inequality of two leagues may be ſuppoſed to be the greateſt that can take place on the ſurface; for the higheſt mountains exceed not a league in height; and the moſt profound parts of the ocean, it is probable, are not above a league in depth. Thus my theory perfectly coincides with practice. The earth's equator could not, at firſt, be elevated more than ſix leagues and a half above the poles; but the changes produced on the ſurface might give it a ſtill greater elevation. Natural hiſtory

hiſtory wonderfully ſupports this opinion; for, in the preceding diſcourſe, we have proved, that, from the tides and other motions of the waters, have proceeded mountains, and all the other inequalities on the ſurface of the globe; and that, at great depths, as well as upon the greateſt heights, bones, ſhells, and other relics of ſea and land animals, have been diſcovered.

From what has been obſerved, it may be conjectured, that, in order to find primitive earth, and ſubſtances which have never been removed from their original ſtations, we muſt dig in countries near the poles, where the bed of unmoved earth will be thinner than in ſouthern climates.

In fine, if the meaſurement by which the figure of the earth was determined be ſtrictly ſcrutinized, we ſhall find that it is not altogether free from hypothetical reaſoning: For it proceeded on the ſuppoſition that the earth was a regular curve: But, as the earth is liable to conſiderable and conſtant changes from a thouſand cauſes, it is impoſſible that it could have retained any perfectly regular figure; and hence, agreeable to our theory, and the opinion of Newton, the poles might originally be only flattened a 230th part. Beſides, though we have the exact length of a degree at the equator and polar circle, yet we have not the exact length of a degree in France; and the meaſures of M. Picard have never been confirmed. It may be added,

added, that the diminution and increafe in the motion of the pendulum agree not with the conclufions drawn from meafurement; and that, on the contrary, they correfpond very nearly with the theory of Newton. Thefe circumftances tend farther to convince us, that the poles are not depreffed above a 230th part; and that, if there be any difference, it can proceed from nothing but the inequalities produced on the furface by the waters, and other external caufes. But thefe inequalities are by no means fo regular as to juftify any hypothefis, which fuppofes the meridians to be ellipfes, or any other perfect curves. Hence it appears, that, though many degrees fhould be fucceffively meafured in different regions, we cannot, by that alone, afcertain the exact depreffion of the poles, nor determine how much it exceeds or falls fhort of a 230th part.

May we not likewife conjecture, that, if the inclination of the earth's axis has been changed, this effect could not be produced but by the changes on the furface, fince all the other parts are homogeneous; that this variation is, of courfe, too fmall to be perceived by aftronomers; and that, if the earth be not difturbed by a comet, or fome other external caufe, its axis will for ever preferve its prefent and original inclination?

Not to omit any conjecture that feems reafonable, may we not fuppofe, that, as the mountains and other inequalities on the furface of the

the earth, have originated from the action of the tides, thoſe which we perceive in the moon have been produced by a ſimilar cauſe? The mountains of the moon are indeed higher than thoſe of the earth; but her tides are likewiſe ſtronger; becauſe the earth, the ſize of which is much larger, raiſes the tides of the moon with a ſuperior force. This effect would be greatly augmented, if the moon, like the earth, had a quick diurnal motion. But, as the moon uniformly preſents the ſame face to the earth, the tides are raiſed only in proportion to the motion occaſioned by her librations, which alternately expoſe to our view a ſmall ſegment of her other hemiſphere. This cauſe, however, muſt produce tides very different from thoſe of our ſeas; and their effects will, of courſe, be much leſs conſiderable, than if the moon had poſſeſſed a diurnal revolution round her axis, equally quick as the rotation of the earth.

I ſhould compoſe a volume equal to that of Burnet or Whiſton, were I to extend the ideas preſented by the above theory; and were I, in imitation of the laſt-mentioned author, to clothe them in a geometrical dreſs, I might add conſiderably to their importance. But I have always thought, that hypotheſes, however probable, deſerve not to be treated ſo pompouſly. It is apt to give them the air of quackery and impoſition.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE II.

Of the System of Whiston *.

THIS author begins his theory with a dissertation on the creation of the world. He alleges, that the account given of it by Moses is not properly understood; and that, in inquiries of this kind, men, contenting themselves with the most evident and superficial views, give too little of their attention to nature, reason, and philosophy. The common notions, he observes, concerning the six days work, are false; and the description of Moses is not an exact or philosophic account of the creation and origin of the universe, but only an historical

* See a new Theory of the Earth by Will. Whiston, London, 1708.

narrative of the formation of the terreſtrial globe. The earth, in his eſtimation, formerly exiſted in chaos, and, at the time mentioned by Moſes, it only received a form, ſituation, and conſiſtence, neceſſary for the habitation of mankind. I ſhall not give a detail of Whiſton's proofs, nor enter upon a formal refutation of them, but content myſelf with a ſhort view of his theory, which will ſhow it to be contrary to the ſcriptures, and, of courſe, that his proofs muſt be falſe. Beſides, he treats this matter more like a polemical divine than a philoſopher.

Leaving theſe falſe principles, he proceeds to ſome ingenious notions, which, though ſingular, will not, to thoſe who are influenced by the enthuſiaſm of ſyſtem, appear to be deſtitute of probability. He tells us, that the ancient Chaos, from which the earth originated, was the atmoſphere of a comet; that the annual motion of the earth began when it received its new form; but that its diurnal motion commenced not till the fall of Adam; that the ecliptic cut the tropic of Cancer in a point preciſely oppoſite to Paradiſe, which was ſituated on the north-weſt frontier of Aſſyria; that, before the deluge, the year began at the autumnal equinox, and that the orbits of the earth and planets were then perfect circles; that the deluge commenced on the 18th of November, in the year of the Julian period 2365, or 2349 before Chriſt; that, previous to the deluge, the ſolar and lunar

year were the ſame, and conſiſted exactly of 360 days; that a comet, deſcending in the plane of the ecliptic to its perihelion, on the very day that the deluge began, made a near approach to the earth; that there is a great heat in the bowels of the earth, which is conſtantly expanding from the centre to the circumference; that the figure of the earth reſembles an egg; that the mountains are the lighteſt parts of the globe, &c. He then attributes to the deluge all the changes the earth has undergone, blindly adopts Woodward's theory, uſes indiſcriminately all that author's remarks on the preſent ſtate of the earth; but aſſumes more the air of an original, when he treats of its future condition. The earth, ſays Mr Whiſton, will be conſumed by fire; and its deſtruction will be preceded by earthquakes, thunder, and hideous meteors; the ſun and moon will aſſume a dreadful aſpect; the heavens will ſeem to fall; and the whole earth will be in flames. But, after the fire ſhall have devoured every impurity of this globe, and vitrified and rendered it tranſparent as the pureſt cryſtal, the ſaints and ſpirits of the bleſſed ſhall take poſſeſſion of it, and there remain till the general judgment.

This hypotheſis appears, at firſt view, to be extravagant and fantaſtical. But the author has managed his ideas with ſuch dexterity, and placed them in ſo ſtrong a light, that they no longer have the air of abſolute chimeras. He has

adorned his subject with much science and ingenuity: And it is astonishing, that, from such a medley of strange notions, he should have been able to compose a system so plausible. But it is not to the vulgar that it has this brilliant appearance; the learned are more easily deceived by the glare of erudition, and the force of new ideas. Mr Whiston was a celebrated astronomer. Accustomed to contemplate the heavens, to measure the motions of the stars, and to consider the great phænomena of nature, he could never imagine that this grain of sand, which we inhabit, occupied more the attention of its Creator than the universe, which contains, in the vast regions of space, millions of other suns and other worlds. He alleges, that Moses has not given us the history of the first creation of this globe, but only a detail of those circumstances which attended its receiving a form fit for the habitation of men, when the Almighty transformed it from the state of a comet to that of a planet. Comets, owing to the eccentricity of their orbits, are subject to dreadful vicissitudes: Sometimes, like that of 1680, they are a thousand times hotter than melted iron, and sometimes a thousand times colder than ice: They cannot, therefore, furnish habitation to any creatures of which we can form a conception; or rather, they are altogether uninhabitable.

The planets, on the contrary, are tranquil bodies; their diſtances from the ſun vary but little; and their temperature continues ſo nearly the ſame, that it permits plants and animals to grow and to multiply.

In the beginning, ſays Mr. Whiſton, God created the univerſe; but the earth was then an uninhabitable comet, and ſubject to ſuch alternate extremes of cold and heat, that its matter, being ſometimes liquified and ſometimes frozen, was in the form of chaos, or an abyſs, ſurrounded with utter darkneſs: *And darkneſs covered the face of the deep.* This chaos was the atmoſphere of the comet, a body compoſed of heterogeneous materials, having its centre occupied with a globular, ſolid, hot nucleus, of about 2000 leagues in diameter, round which was an extenſive maſs of a thick fluid, mixed with heterogeneous and undigeſted materials, like the chaos of the ancients, *rudis indigeſtaque moles.* This great atmoſphere contained few dry, ſolid, or earthy particles, and ſtill leſs of water or air; but it was amply filled with thick and heavy fluids, mixed, agitated, and jumbled together in the utmoſt confuſion. Such was the condition of the earth when ſix days old: But, next day, that is, on the firſt day of the creation, when the eccentric orbit of the comet was changed into an ellipſe, nearly circular, every thing aſſumed its proper place; the different materials arranged themſelves according

ing to their specific gravities; the heavy fluids sunk down, and left to the earthy, watery, and aerial substances, the superior regions. These also descended in the order of their gravities; first the earth, then the water, and, lastly, the air. In this manner, the immense volume of chaos was reduced to a moderate sphere, the centre of which is a solid body that still retains the heat it received from the sun, when formerly the nucleus of a comet. This heat may easily last 6000 years, since the comet 1680 would require 50,000 before it cooled. Round the solid and burning nucleus, at the centre of the earth, is placed the heavy fluid which descended first, and formed the great abyss, upon which the earth floats like a cork on quick-silver. But as the earthy parts were originally mixed with a great body of water, they, in descending, drove before them a part of this water, which was confined there when the earth consolidated, and formed a stratum concentric with the heavy fluid that surrounds the nucleus. Thus, the great abyss is composed of two concentric circles, the interior being a heavy fluid, and the superior water, upon which last the earth is immediately founded. From this admirable arrangement, produced by the atmosphere of a comet, are to be deduced the theory of the earth, and an explication of all its phænomena!

After the atmosphere of the comet had been freed from the solid and earthy particles, a pure air

air only remained, through which the rays of the ſun inſtantly penetrated, and produced light: *Let there be light; and there was light.* The vaſt columns or beds of which the earth is compoſed, being formed with ſo much precipitation, is the reaſon why they differ ſo much in denſity; the heavier ſunk deeper into the abyſs than the lighter, and, of courſe, gave riſe to mountains and valleys: Theſe inequalities, before the deluge, were differently ſituated from what they are at preſent. Inſtead of that vaſt valley which contains the ocean, many ſmall caverns were diſperſed over the globe, each of which contained a part of the waters. The mountains were then at greater diſtances, and formed not large chains. But the earth was a thouſand times more fertile, and contained a thouſand times more inhabitants; and the life of man, and of the other animals, was ten times longer. All theſe effects were produced by the ſuperior heat of the central fire, which gave birth to a greater number of plants and animals, and, at the ſame time, beſtowed on them a degree of vigour that enabled them to exiſt long, and to multiply abundantly. But this heat had a miſerable effect upon the diſpoſitions of men and other animals: It augmented the paſſions, robbed man of his innocence, and diminiſhed the ſagacity of the brute creation. All creatures, except the fiſhes, who inhabited a colder element, felt the influence of the central heat, became vicious,

 and

and merited death. This universal death was accordingly inflicted, on Wednesday the 28th day of November, by a dreadful deluge, which lasted 40 days and 40 nights, and was occasioned by the tail of a comet meeting with the earth, in returning from its perihelion.

The tail of a comet is the lightest part of its atmosphere. It is a transparent and subtile vapour raised by the heat of the sun from the body of the comet. This vapour, which is composed of aerial and watery particles extremely rarified, follows the comet in its descent to its perihelion, and goes before the comet in its ascent, its situation being always opposite to the sun, as if it had an affection for the shade, and wished to avoid the scorching rays of the sun. This column of vapour is often of an immense extent; and its length always increases in proportion as the comet approaches nearer the sun. Now, as many comets descend below the annual orbit of the earth, it is not surprising that the earth should sometimes be involved in this vapour. This dreadful event happened at the time of the deluge. The tail of a comet, in two hours, will discharge a quantity of water equal to that contained in the whole ocean. In fine, this tail is what Moses calls the cataracts of heaven: *And the cataracts of heaven were opened.* The globe of the earth, when it meets with a comet's tail, must necessarily, in its passage through this body of vapour, appropriate part

part of its materials. Every thing that comes within the ſphere of the earth's attraction muſt fall upon it, and muſt fall in the form of vapour, ſince the tail itſelf principally conſiſts of that element. In this manner, rain may come from the heavens in ſuch torrents, as to produce an univerſal deluge, and to ſurmount the tops of the higheſt mountains.

Our author, however, unwilling to go beyond the letter of the ſacred writings, does not aſcribe the deluge to this rain alone, which he has choſen to bring from ſo great a diſtance. He takes advantage of water wherever he can find it: The great abyſs, as we have ſeen, contains a conſiderable quantity. The earth, in its approach towards the comet, would feel the force of its attraction; the waters in the great abyſs would be ſo agitated with a motion ſimilar to that of the tides, as would neceſſarily break the ſhell or cruſt in many places, and make the water ruſh out upon the ſurface: *And the fountains of the abyſs were opened.*

But how, it may be aſked, was this vaſt collection of water, ſo liberally furniſhed by the great abyſs, and by the comet's tail, afterwards diſpoſed of? Our author is not embarraſſed by this circumſtance. As ſoon as the earth eſcaped from the comet, the flux and reflux of the great abyſs neceſſarily ceaſed. From that moment the waters on the ſurface ruſhed down with violence by the ſame channels out of which they

had

had issued. The great abyss swallowed up not only its own water, but all that had been deposited by the comet, which it was sufficiently enabled to contain; because, during its agitation, and when it broke the crust, it had greatly enlarged its dimensions, by pushing the earth farther from it on all sides. It was at this time, likewise, that the earth, which was formerly a sphere, assumed its elliptical figure. This effect was produced by the centrifugal force occasioned by the diurnal motion of the earth, and by the attraction of the comet; for the earth, when passing through the tail of the comet, was so situated, that its equatorial parts were nearest that star; and, of course, the power of the comet's attraction, concurring with the earth's centrifugal force, elevated the equatorial regions with the greater facility, because the crust was broken in an infinite number of places, and because the flux and reflux of the abyss pushed more violently against the equator than any where else.

This is the history Mr. Whiston gives of the creation, of the causes of the universal deluge, of the longevity of the Antedeluvians, and of the figure of the earth. All these difficult subjects seem to have given our author very little trouble. But he appears to be greatly puzzled concerning Noah's ark. In that dreadful confusion, produced by the conjunction of the tail of a comet, and by the waters of the great abyss, and in that horrible period, when not only the

the elements of this globe were confounded, but when the heavens concurred with the bowels of the earth in producing new elements to increafe the chaos, how is it to be imagined that the ark could float tranquilly, with its numerous and valuable cargo, upon the furface of the waves? Here our author ftruggles hard, in order to account for the prefervation of the ark. But, as his reafoning upon this fubject appears to be inconclufive, ill-imagined, and heterodox, I fhall only obferve, how hard it is for a man, who had explained objects fo great and furprifing, without having recourfe to a fupernatural power, to be ftopped in his career by a trifling circumftance. But he chooses to rifk drowning himfelf along with the ark, rather than to afcribe the prefervation of this precious veffel to the interpofition of the Almighty!

I fhall only make a fingle remark upon this fyftem, of which I have given a faithful abridgement. Whenever men are fo prefumptuous as to attempt a phyfical explanation of theological truths; whenever they allow themfelves to interpret the facred text by views purely human; whenever they reafon concerning the will of the Deity, and the execution of his decrees; they muft neceffarily involve themfelves in obfcurity, and tumble into a chaos of confufion, like the author of this whimfical fyftem, which, notwithftanding all its abfurdities, has been received

ceived with great applauſe. Mr. Whiſton neither doubted of the truth of the deluge, nor of the authenticity of the ſacred writings. But, as phyſics and aſtronomy occupied his principal attention, he miſtook paſſages of holy writ for phyſical facts, and for reſults of aſtronomical obſervations; and ſo ſtrangely jumbled divinity with human ſcience, that he has given birth to the moſt extraordinary ſyſtem that perhaps ever did or ever will appear.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE III.

Of Burnet's Theory *.

MR. BURNET is the first author who discovered enlarged views of the present subject, and who treated of it in a systematic manner. He was a man of genius and of taste: His work acquired great reputation, and was of course, criticised by many of the learned, and, among others, by Mr. Keill, who scrutinizing the subject as a geometer, demonstrated the errors of Burnet's theory in a treatise entitled, *An examination of the Theory of the Earth*. Mr. Keill likewise refuted the system of Whiston; but he treated the latter in a manner very different from the former. He even appears, in many particulars,

* Thomas Burnet. Telluris theoria sacra, orbis nostri originem et mutationes generales, quas aut jam subiit, aut olim subiturus est, complectens. Londini 1681.

particulars, to adopt the opinions of Whiston; and considers the notion, that the deluge was occasioned by the tail of a comet as exceedingly probable. But, to return to Burnet: His book is written with elegance. He knows how to paint the grandest images and the most magnificent scenes. His plan is elevated; but, being defective in proper materials, he often fails in the execution. His reasonings and his proofs are feeble; but the boldness with which he writes makes the reader lose sight of all his imperfections.

He begins with alleging, that the earth, before the deluge, was very different from what it is now. It was at first, says he, a fluid mass, composed of matters of every species, and of all kinds of figures, the heaviest of which descended to the centre, and formed a hard and solid body. The waters took their station round this body; and all lighter fluids rose above the water. Thus, between the coat of air, and that of water, a coat of oily matter was interposed. But, as the air was then full of impurities, and contained great quantities of earthy particles, these gradually subsided upon the coat or stratum of oil, and formed a crust composed of earth and oil: This crust was the first habitable part of the earth, and the first abode of man and other animals. The land thus formed was light, fat, and adapted to cherish the tenderness of the original germs. The surface of the earth was level

and

and uniform, without mountains, ſeas, or other inequalities. But it remained in this ſtate about ſixteen centuries only; for the heat of the ſun gradually drying the cruſt, produced, at firſt, ſuperficial fiſſures or cracks only; but, in proceſs of time, theſe fiſſures penetrated deeper, and increaſed ſo much in their dimenſions, that, at laſt, they entirely perforated the cruſt. In an inſtant, the whole earth ſplit in pieces, and fell into the great abyſs of waters which it formerly ſurrounded. This wonderful event was the univerſal deluge.

But all theſe maſſes of earth, in falling into the abyſs, carried along with them vaſt quantities of air, and they daſhed againſt each other, and accumulated and divided ſo irregularly, that great cavities filled with air were left between them. The waters gradually opened paſſages into theſe cavities, and, in proportion as the cavities were filled with the water, the ſurface of the earth began to diſcover itſelf in the moſt elevated places; and, at laſt, the waters appeared no where but in thoſe extenſive valleys which contain the ocean. Thus our ocean is a part of the ancient abyſs; the reſt of it remains in the internal cavities, with which the ſea has ſtill a communication. Iſlands and ſea-rocks are the ſmall fragments, and continents are the large maſſes of the ancient cruſt. As both the rupture and fall of this cruſt were effected in a ſudden and confuſed manner, it is not ſurpriſing that

the ſurface of the preſent earth ſhould be full of mountains, gulfs, plains, and irregularities of every kind.

This ſpecimen is ſufficient to give an idea of Burnet's ſyſtem. It is an elegant romance, a book which may be read for amuſement, but cannot convey any inſtruction. The author was ignorant of the chief phænomena of the earth, and a man of no obſervation. He has drawn every thing from imagination, which often acts both againſt truth and reaſon.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE IV.

Of the System of Woodward *.

OF this author it may be ſaid, that he wanted to build an immenſe edifice upon a foundation leſs firm than ſand, and to conſtruct a world with duſt; for, he aſſerts, that the earth, at the time of the deluge, ſuffered a total diſſolution. In peruſing his book, the firſt idea which preſents itſelf is, that this diſſolution was effected by the waters of the great abyſs. He alleges, that, at the command of God, the abyſs ſuddenly opened, and diffuſed ſuch an enormous quantity of water on the ſurface, as was ſufficient to cover the tops of the higheſt mountains; and

* An Eſſay towards the Natural Hiſtory of the Earth, by John Woodward.

that God ſuſpended the law of coheſion, which inſtantly reduced every ſolid ſubſtance into a powder, &c. He did not conſider, that, by theſe ſuppoſitions, he added to the miracle of the univerſal deluge many other miracles, or, at leaſt, phyſical impoſſibilities, which accord neither with the ſcriptures, nor with the principles of mathematics and of natural philoſophy. But as this author has the merit of collecting many important obſervations, and as he knew better than any former writer the materials of which the globe is compoſed, his ſyſtem, though ill conceived and worſe arranged, has ſeduced, by the luſtre of a few ſtriking facts, many weak men into a belief of his general concluſions.

We ſhall now give a ſhort view of his theory, by which we will be enabled to do juſtice to the merit of the author, and put the reader in a condition to judge of the futility of his ſyſtem, and of the falſehood of ſome of his remarks. Mr. Woodward informs us, that he recogniſed with his own eyes all the materials of which the earth in England is compoſed, from the ſurface to the greateſt depths that had been dug; that they were all diſpoſed in beds, or ſtrata; and that, in many of theſe beds, there are ſhells and other productions of the ſea. He then adds, that he was aſſured by his friends and correſpondents, that in all the other countries of the world, the earth was compoſed of the ſame materials; and that ſhells are found, not only in the plains,

plains, and in ſome particular parts, but on the higheſt mountains, in the deepeſt pits, and in an infinite number of different places. He obſerved, that the beds were all horizontal, and placed over each other, like matters tranſported by the waters, and depoſited in the form of ſediment. Theſe general remarks, which are founded in truth, are followed with ſome particular obſervations, by which he demonſtrates, that the foſſil ſhells incorporated with the ſtrata are real ſea-ſhells, and not peculiar minerals, or *luſus naturæ*, &c.

To theſe obſervations, though partly made before him, he has added others of a more ſuſpicious nature. He aſſerts, that the materials of the different ſtrata are arranged according to their ſpecific gravities. This aſſertion is not conſiſtent with truth: For we every day ſee ſolid rocks placed above clay, ſand, pit-coal, bitumen, and other comparatively light bodies. If, indeed, it were uniformly found, through the whole earth, that the upper ſtratum was bitumen, followed ſucceſſively by ſtrata of chalk, marl, clay, ſand, ſtone, marble, and metals, it would, in that caſe, be probable that all thoſe materials had been precipitated at once: And this our author affirms with confidence, though the moſt ſuperficial obſerver needs only his eyes to convince him, that heavy ſtrata are often found above light ones; and, conſequently, that theſe ſediments could not be depoſited at the ſame time, but muſt have been tranſported and

 depoſited

deposited by the ocean at successive periods. As this is the foundation of Woodward's system, and is manifestly false, we shall follow him no farther than to show how an erroneous principle produces false relations and bad conclusions.

All the strata which compose the earth, says our author, from the tops of the highest mountains to the deepest mines, are placed according to their respective specific gravities. Hence, he concludes, the whole must have been in a state of dissolution, and precipitated at the same time. But at what time, in what menstruum, was it dissolved? In the water, says Mr. Woodward, and at the time of the deluge. But there is not water enough on the globe to produce this effect; for there is more earth than water; and the bottom of the sea itself is earth. Very well, he replies: But there is enough of water in the central parts of the earth; and nothing more was wanting than to bestow on it the power of dissolving every terrestrial substance, except sea-shells; to find a proper method of making the waters return to the abyss; and to make all this correspond with the history of the deluge. Behold a system, of which the author could not prevail on himself to form a doubt; for, when it was objected to him, that water could not dissolve water, rocks, and metals, especially in forty days, the time of the waters remaining on the earth; he replied simply, that the event, however, did happen. When it was demanded

demanded of him, how the waters of the abyſs could diſſolve the whole earth, and yet preſerve the ſhells? He anſwered, that he never proved that this water was a diſſolvent; but that, from facts, it was clear that the earth had been diſſolved, and that the ſhells were preſerved. Laſtly, When it was demonſtrated to him, that his ſyſtem was uſeleſs, as it was neither ſupported by reaſon nor by facts, he ſaid, We had only to ſuppoſe that, at the time of the deluge, the laws of gravity and of coheſion were ſuddenly ſtopped, and, upon this ſuppoſition, the diſſolution of the ancient world admitted of an eaſy explanation. But, it was obſerved to him, if the force of coheſion was ſuſpended, Why were not the ſhells diſſolved along with the reſt? Here he gave a harangue on the organization of ſhells and of animal bones, tending to prove that their texture was fibrous, and different from that of minerals; that their coheſion was likewiſe different; and that, after all, we have only to ſuppoſe that the powers of gravity and of coheſion did not entirely ceaſe, but that they were diminiſhed to ſuch a degree, as enabled them to diſſolve the parts of minerals, but not thoſe of animals. I ſhall conclude with remarking, that our author's philoſophy was not equal to his talent for obſervation; it is therefore unneceſſary to give a formal refutation of abſurd notions, eſpecially when they proceed upon conjectures which are contrary both to the laws of probability and of mechanics.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE V.

Examination of ſome other Syſtems.

THE three hypotheſes formerly animadverted upon have many things in common: They all agree in this, that, at the time of the deluge, both the external and internal form of the earth was changed. But none of theſe theoriſts conſidered, that the earth, before the deluge, was inhabited by the ſame ſpecies of men and animals; and, conſequently, that it muſt have been nearly the ſame, both in figure and ſtructure, as it is at preſent. We are informed by the ſacred writings, that, before the deluge, there were rivers, ſeas, mountains, and foreſts; that moſt of theſe mountains and rivers remained nearly in their former ſituation; the Tigris and Euphrates,

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for example, ran through Paradiſe; that the Armenian mountain on which the ark reſted, was, at the deluge, one of the higheſt mountains of the earth, as it is at this day; and that the ſame plants and the ſame animals, which inhabited the earth before the deluge, continue ſtill to exiſt; for we are told of the ſerpent, of the crow, and of the pigeon that carried the olive-branch into the ark. Tournefort indeed alleges, that there are no olives within 400 leagues of Mount Araret, and affects to be witty on this head. It is, however, indiſputable, that there were olives in the neighbourhood of this mountain at the time of the deluge; for Moſes aſſures us of the fact in the moſt expreſs manner. Beſides, it is not ſurpriſing, that, in the courſe of 4000 years, the olives ſhould be extirpated in theſe provinces, and multiplied in others. It is, therefore, contrary both to ſcripture and reaſon, that theſe authors have ſuppoſed the earth, before the deluge, to have been totally different from what it is now; and this oppoſition between their hypotheſes and the ſacred writings, as well as ſound philoſophy, is ſufficient to diſcredit their ſyſtems, although they ſhould correſpond with ſome phænomena *. Burnet, who wrote firſt, gives neither facts nor obſervations in ſupport of his ſyſtem. Woodward's book is only a ſhort eſſay, in which he promiſes much more than he was able to perform; it is only a project, with-

* See Voyage du Levant, vol. ii. p. 336.

out any degree of execution. He makes uſe of two general remarks, 1. That the earth is every where compoſed of materials which had formerly been in a ſtate of fluidity, and which had been depoſited by the waters in horizontal beds. 2. That, in the bowels of many parts of the earth, there are an infinite number of ſea-bodies. To account for theſe facts, he has recourſe to the univerſal deluge; or rather, he appears to employ theſe as proofs of the deluge. But, like Burnet, he falls into evident contradictions; for it is abſurd to ſuppoſe, with theſe authors, that, before the deluge, there were no mountains, ſince we are expreſsly told, that the waters roſe 15 cubits above the tops of the higheſt mountains. On the other hand, it is not ſaid that the waters deſtroyed or diſſolved the mountains. In place of this extraordinary diſſolution, the mountains remained firm in their original ſituations, and the ark reſted upon the one which was firſt deſerted by the waters. Beſides, it is impoſſible to imagine, that, during the ſhort time the deluge continued, the waters could diſſolve the mountains, and the whole fabric of the earth. Is it not abſurd to ſuppoſe, that, in the ſpace of forty days, the hardeſt rocks and minerals were diſſolved by ſimple water? Is it not a manifeſt contradiction to admit this total diſſ-
on, and yet to maintain that ſhells, bones, d other productions of the ſea, were able to ſt a menſtruum to which the moſt ſolid materials

terials had yielded? Upon the whole, I cannot hesitate in pronouncing, that Woodward, though furnished with excellent facts and observations, has produced but a weak and inconsistent theory.

Whiston, who wrote last, has greatly improved upon the other two; and, though he has given loose reins to his imagination, it cannot be said that he falls into contradiction. He advances many things which are incredible; but they are neither absolutely nor apparently impossible. As we are ignorant of what materials the centre of the earth is composed, he thinks himself intitled to suppose it a solid nucleus, surrounded with a ring of heavy fluid matter, and then follows a ring of water, upon which the external crust is supported. In this ring of water, the different parts of the crust sunk more or less in proportion to their gravities, and gave rise to mountains and inequalities on the surface of the earth. But our astronomer here commits a blunder in mechanics. He considered not, that the earth, on this supposition, must have formed one uniform arch; and, consequently, that it could not be supported by the water, and far less could any part of this arch sink deeper than another. If this be excepted, I doubt whether he has fallen into any other physical blunder: He has, however, committed many errors both in metaphysics and theology. In fine, it cannot be denied absolutely, that the earth, in meeting with the tail of a comet, would be deluged,

luged, eſpecially if it be allowed to the author, that the tails of comets contain watery vapours. Neither is it abſolutely impoſſible, that the tail of a comet, in returning from its perihelion, ſhould burn the earth, if we ſuppoſe, with Mr. Whiſton, that the comet paſſed very near the ſun's body. The ſame obſervations may be made upon the reſt of his ſyſtem. But, though his notions be not abſolutely impoſſible, when taken ſeparately, they are ſo exceedingly improbable, that the whole aſſemblage may be regarded as exceeding the bounds of human credulity.

Theſe three are not the only books which have been written upon the theory of the earth. In 1729, M. Bourguet publiſhed, along with his *Philoſophical Letters on the formation of Salts, &c.* a memoir, in which he gives a ſpecimen of a ſyſtem which he had projected; but the execution of it was prevented by the death of the author. It muſt be acknowledged, that no man was more induſtrious and acute in making obſervations, and in collecting facts. To him we are indebted for remarking the correſpondence between the angles of mountains, which is the chief key to the theory of the earth. He arranges the materials he had collected in the beſt order. But, with all theſe advantages, it is probable, that he would not have ſucceeded in giving a phyſical hiſtory of the changes which have happened in the earth; and he appears not to have diſcovered the cauſes of thoſe effects which he

he relates. To be convinced of this remark, we have only to take a view of the propoſitions he deduces from thoſe phænomena which muſt have been the foundation of his theory. He ſays, that the earth was formed at once, and not ſucceſſively; that its figure and diſpoſition demonſtrate that it was formerly in a fluid ſtate; that the preſent condition of the earth is very different from what it was ſome ages after its firſt formation; that the matter of the globe was originally more ſoft than after its ſurface was changed; that the condenſation of its ſolid parts diminiſhed gradually with its velocity; ſo that, after a certain number of revolutions round its own axis, and round the ſun, its original ſtructure was ſuddenly diſſolved; that this happened at the vernal equinox; that the ſea-ſhells inſinuated themſelves into the diſſolved matters; that the earth, after this diſſolution, aſſumed its preſent form; and that, as ſoon as the fire or heat operated upon it, its conſumption gradually began, and, at ſome future period, it will be blown up with a dreadful exploſion, accompanied with a general conflagration, which will augment the atmoſphere, and diminiſh the diameter of the globe; and then the earth, in place of ſtrata of ſand or clay, will conſiſt only of beds of calcined materials, and mountains compoſed of amalgams of different metals.

This is a ſufficient view of the ſyſtem which M. Bourguet deſigned to compoſe. To gueſs at

the paſt, and to predict the future, nearly in the ſame manner as others have gueſſed and predicted, requires but a ſmall effort of genius. This author had more erudition than ſound and general ideas. He appears not to have had the capacity of forming enlarged views, or of comprehending the chain of cauſes and effects.

In the Leipſic Tranſactions, the celebrated Leibnitz publiſhed a ſketch of an oppoſite ſyſtem, under the title of Protogæa. The earth, according to Bourguet and others, was to be conſumed by fire. But Leibnitz maintains, that it originated from fire, and that it has undergone innumerable changes and revolutions. At the time that Moſes tells us the light was divided from the darkneſs, the greateſt part of the earth was in flames. The planets, as well as the earth, were originally fixed and luminous ſtars. After burning for many ages, he alleges, that they were extinguiſhed from a deficiency of combuſtible matter, and that they became opaque bodies. The fire, by melting the matter, produced a vitrified cruſt; and the baſis of all terreſtrial bodies is glaſs, of which ſand and gravel are only the fragments. The other ſpecies of earth reſulted from a mixture of ſand with water and fixed ſalts; and, when the cruſt had cooled, the moiſt particles, which had been elevated in the form of vapour, fell down, and formed the ocean. Theſe waters at firſt covered the whole ſurface, and even overtopped the higheſt

highest mountains. In the estimation of this author, the shells, and other spoils of the ocean, which every where abound, are indelible proofs that the earth was formerly covered with the sea; and the great quantity of fixed salts, of sand, and of other melted and calcined matters shut up in the bowels of the earth, demonstrate, that the conflagration had been general, and that it had preceded the existence of the ocean. These ideas, though destitute of evidence, are elevated, and bear conspicuous marks of ingenuity. The thoughts have a connection, the hypotheses are not impossible, and the consequences which might be drawn from them are not contradictory. But the great defect of this theory is, that it applies not to the present state of the earth. It only explains what passed in ages so remote, that few vestiges remain; a man may, therefore, affirm what he pleases, and what he says will be accompanied with more or less probability, in proportion to the extent of his talents. To maintain, with Whiston, that the earth was originally a comet, or with Leibnitz, that it was a sun, is to assert what is equally possible or impossible; it would, therefore, be ridiculous to investigate either by the laws of probability. The instantaneous creation of the world destroys the notion of the globe's being covered with the ocean, and of that being the reason why sea-shells are so much diffused through different parts of the earth; for, if that

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had been the caſe, it muſt of neceſſity be allowed, that ſhells, and other productions of the ocean, which are ſtill found in the bowels of the earth, were created long prior to man, and other land-animals. Now, independent of ſcripture-authority, is it not reaſonable to think that the origin of all kinds of animals and vegetables is equally ancient?

M. Scheutzer, in a diſſertation addreſſed to the Academy of Sciences in 1708, attributes, like Woodward, the change, or rather new creation of the globe, to the deluge. To account for the formation of mountains, he tells us, that God, when he ordered the waters to return to their ſubterraneous abodes, broke, with his Almighty hand, many of the horizontal ſtrata, and elevated them above the ſurface of the earth, which was originally level. The whole diſſertation was compoſed with a view to ſupport this ridiculous notion. As it was neceſſary that theſe eminences ſhould be of a ſolid conſiſtence, M. Scheutzer remarks, that God only raiſed them from places which abounded in ſtones. Hence, ſays he, thoſe countries, like Switzerland which are very ſtony, are likewiſe mountainous; and thoſe, like Flanders, Holland, Hungary, and Poland, which are moſtly compoſed of ſand and clay to great depths, have few or no mountains *.

* Vid. Hiſt. de l'Acad. 1708. p. 32.

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This author, like Woodward, blends phyfics and theology; and, though he has made fome good obfervations, the fyftematic part of his work is weaker and more puerile than that of any of his predeceffors. He has even defcended to declamation, and abfurd pleafantries. The reader, if he defires to fee them, may confult his *Pifcium Querelæ*, &c. not to mention his *Phyfica Sacra*, confifting of feveral volumes in folio, a weak performance, fitter for the amufement of children than the inftruction of men.

Steno, and fome others, have attributed the origin of mountains, and other inequalities upon the furface of the earth, to particular inundations, earthquakes, &c. But the effects of thefe fecondary caufes could produce nothing but flight changes. Thefe caufes may co-operate with the firft caufe, namely, the tides, and the motion of the fea from eaft to weft. Befides, Steno has given no theory, nor even any general facts, upon this fubject *.

Ray alleges, that all mountains have been produced by earthquakes, and has written a treatife to prove the point. When we come to the article of volcano's, we fhall examine the foundation of this opinion.

We cannot omit obferving here, that Burnet, Whifton, Woodward, and moft other authors, are fallen into an error which deferves to be rectified. They uniformly regard the deluge as

* Vide Differt. de Solido intra Solidum nato, &c.

an effect within the compafs of natural caufes, although the fcripture reprefents it as an immediate operation of the Deity. It is beyond the power of any natural caufe to produce on the furface of the earth a quantity of water fufficient to cover the higheft mountains: And, although a caufe could be imagined adequate to this effect, it would ftill be impoffible to find another caufe capable of making the waters difappear. Granting that Whifton's water proceeded from the tail of a comet, we deny that any of them could iffue from the abyfs, or that the whole could return into it; for the abyfs, according to him, was fo environed and preffed on all fides by the terreftrial cruft, that it was impoffible the comet's attraction could produce the leaft motion in the fluid it contained, far lefs any motion refembling the tides: Hence, not a fingle drop could either proceed from, or enter into, the great abyfs. Unlefs, therefore, it is fuppofed, that the waters which fell from the comet were annihilated by a miracle, they would for ever have remained on the furface, and covered the tops of the higheft mountains. The impoffibility of explaining any effect by natural caufes, is the moft effential character of a miracle. Our authors have made feveral vain efforts to account for the deluge. Their errors in phyfics, and in the fecondary caufes they employ, prove the truth of the fact, as related in fcripture, and demonftrate, that the universal deluge could not be accom-

accompliſhed by any other cauſe than the will of the Deity.

Beſides, it is apparent, that it was not at one time, nor by the ſudden effect of a deluge, that the ſea left uncovered thoſe continents which we inhabit: it is certain, from the authority of ſcripture, that the terreſtrial Paradiſe was in Aſia, and that Aſia was inhabited before the deluge; conſequently, the waters, at that period, covered not this large portion of the globe. The earth, before the deluge, was nearly the ſame as now. This enormous quantity of water, poured out by Divine juſtice upon guilty men, deſtroyed every living creature; but it produced no change on the ſurface of the earth; it deſtroyed not even the plants; for the pigeon returned to the ark with an *olive branch* in her bill.

Why then ſhould we ſuppoſe, with many naturaliſts, that the waters of the deluge totally changed the ſurface of the globe, even to the depth of two thouſand feet? Why imagine that the deluge tranſported thoſe ſhells, which are found at the depth of ſeven or eight hundred feet, immerſed in rocks and in marble? Why refer to this event the formation of hills and mountains? And how is it poſſible to imagine, that the waters of the deluge tranſported banks of ſhells of 100 leagues in length? I perceive not how they can perſiſt in this opinion, unleſs they admit a double miracle, one to create water, and

another to tranſport ſhells. But as the firſt only is ſupported by holy writ, I ſee no reaſon for making the ſecond an article of faith.

On the other hand, if the waters of the deluge had retired ſuddenly, they would have carried off ſuch immenſe quantities of mud and ſoil, as would have rendered the land unfit for culture till many ages after this inundation. In the inundation which happened in Greece, the country that was covered remained barren for three centuries *. Thus the deluge ought to be regarded as a ſupernatural mode of chaſtiſing the wickedneſs of men, not as an effect proceeding from any natural cauſe. The univerſal deluge was a miracle, both in its cauſe and in its effects. It appears from the ſacred text, that the ſole deſign of the deluge was the deſtruction of men and other animals, and that it changed not in any manner the ſurface of the earth; for, after the retreat of the waters, the mountains, and even the trees, kept their former ſtations, and the land was ſuited for the culture of vines and other fruits of the earth. It might be aſked, if the earth was diſſolved in the waters, or, if the waters were ſo much agitated as to tranſport the ſhells of India into Europe, how the fiſhes, which entered not into the ark, were preſerved?

The notion, that the ſhells were tranſported and left upon the land by the deluge, is the ge-

* Vide acta erudit. Lipſ. 1691, p. 100.

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neral opinion, or rather ſuperſtition, of naturaliſts. Woodward, Scheutzer, and others, call petrified ſhells the remains of the deluge; they regard them as medals or monuments left us by God of this dreadful cataſtrophe, that the memorial of it might never be effaced among men. Laſtly, they have embraced this hypotheſis with ſo blind a veneration, that their only anxiety is to reconcile it with holy writ; and, in place of deriving any light from obſervation and experience, they wrap themſelves up in the dark clouds of phyſical theology, the obſcurity and littleneſs of which derogate from the ſimplicity and dignity of religion, and preſent to the ſceptic nothing but a ridiculous medley of human conceits and divine truths. To attempt an explanation of the univerſal deluge and of its phyſical cauſes; to pretend to give a detail of what paſſed during this great revolution; to conjecture what effects have reſulted from it; to add facts to the ſacred writings, and to draw conſequences from theſe interpolations; is not this a preſumptuous deſire of ſcanning the power of the Almighty? The natural wonders wrought by his beneficent hand, in a uniform and regular manner, are altogether incomprehenſible; his extraordinary operations, or his miracles, ought, therefore, to impreſs us with an awful aſtoniſhment, and a ſilent reſpect.

It may ſtill be urged, that, as the univerſal deluge is an eſtabliſhed fact, is it not lawful to rea-

ſon upon its conſequences? True. But you muſt commence with acknowledging, that the deluge could not poſſibly be the effect of any phyſical cauſe; you muſt regard it as an immediate operation of the Deity; you muſt content yourſelf with what is recorded in ſcripture; and you muſt, above all, avoid blending bad philoſophy with the purity of divine truth. After taking theſe precautions, which a reſpect for the counſels of the Almighty requires, what remains for examination upon the ſubject of the deluge? Do the ſacred writings tell us that the mountains were formed by the deluge? They tell us the reverſe. Do they inform us that the agitation of the waters was ſo great, as to raiſe the ſhells from the bottom of the ocean, and to diſperſe them over the face of the earth? No: The ark moved gently on the ſurface of the waters. Do they tell us, that the earth ſuffered a total diſſolution? By no means. The narration of the ſacred hiſtorian is ſimple and true; that of naturaliſts is complicated and fabulous.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE VI.

Geography.

THE ſurface of the earth is not, like that of Jupiter, divided into alternate bands or belts, parallel to the equator. On the contrary, it is divided, from one pole to the other, into two belts of earth, and two of ſea. The firſt and principal belt is the ancient Continent, the greateſt length of which is a line commencing at the moſt eaſtern point of the north of Tartary, and extending from thence to the neighbourhood of the gulf of Linchidolin, where the Ruſſians fiſh whales; from thence to Tobolſki; from Tobolſki to the Caſpian ſea; from the Caſpian ſea to Mecca; from Mecca to the weſtern part of the country inhabited by the Galli in

Africa; from thence to Monoemuci, or Monomotapa; and, laſtly, to the Cape of Good Hope. This line is about 3600 leagues in length, and is never interrupted but by the Caſpian and the Red Seas, the breadth of which is inconſiderable, and ought not to be regarded, eſpecially as, like our ſeaſons, the whole ſurface of the globe is divided into four parts only.

This greateſt length of the Old Continent lies in a diagonal line; for, if meaſured by a meridian, it will appear, that, from the northernmoſt point of Lapland to the Cape of Good Hope, exceeds not 2500 leagues; and that this line, though ſhorter, meets with greater interruptions from the Baltic and Mediterranean. With regard to all other lines which could be drawn under the ſame meridians in the Old Continent, they muſt ſtill be ſhorter than thoſe we have mentioned. For example, from the moſt ſouthern point of the Iſland of Ceylon to the northernmoſt coaſt of Nova Zembla, is 1800 leagues. In the ſame manner, if the Continent be meaſured by lines parallel to the equator, its greateſt length, without much interruption by ſeas, will ſtretch from Trefana, on the weſt coaſt of Africa, to Ninpo, on the eaſt coaſt of China, which is about 2800 leagues. Another line may begin near Breſt, and extend to the coaſt of Chineſe Tartary, which will be nearly 2300 leagues. From Bergen in Norway, to the coaſt of Kamtſchatka, is only 1800 leagues. All theſe lines are

are much ſhorter than the firſt. Hence the greateſt length of the Old Continent extends from the eaſtern point of Tartary to the Cape of Good Hope, and is about 3600 leagues. *See plate* I.

This line may be conſidered as the middle of the ancient Continent; for, in meaſuring the ſurface on each ſide of it, I find, that on the left, there are 2,471,092¾ ſquare leagues; and, on the right, there are 2,469,687, which is an equality ſo aſtoniſhing, as to render it extremely probable that this line, which is the longeſt, at the ſame time really divides the contents of the ancient Continent.

Hence the Old Continent conſiſts of about 4,940,780 ſquare leagues, which is a fifth part of the ſurface of the globe, and may be regarded as a large belt of earth, with an inclination to the equator of about 30 degrees.

The New Continent is another belt of earth, the greateſt length of which may be taken from the mouth of the river Plata to the lake of the Aſſiniboils. This line paſſes from the mouth of the river Plata to Lake Caracara; from thence to Mataguais, Pocona, Zongo, Mariana, Morua, St. Fe, and Carthagena; then it paſſes through the gulf of Mexico to Jamaica and Cuba; from thence along the peninſula of Florida, through Apalache, Chicachas; and from thence to St. Louis, Fort le Sueur, and terminates in the country bordering on Lake Aſſini-

boils, the extent of which is unknown. *See plate* II.

This line is interrupted only by the Gulf of Mexico, (which may be confidered as a Mediterranean fea,) is about 2500 leagues in length, and divides the New Continent nearly into two equal parts, that on the left containing 1,069,286$\frac{5}{6}$ leagues fquare, and that on the right 1,070,926$\frac{1}{12}$. It is the middle of the belt of land called the New Continent, and is likewife inclined to the equator about 30 degrees, but in an oppofite direction; for that of the Old Continent extends from the north-eaft to the fouth-weft; but that of the New Continent from north-weft to fouth-eaft. The fuperficial contents of the Old and New Continents are about 7,080,993 fquare leagues, not near a third part of the furface of the globe, which contains 25,000,000 fquare leagues.

Of thefe lines, which divide the Continents into two equal parts, it may be remarked, that they both terminate at the fame degrees of north and fouth latitude; and that the two Continents make mutual advances, or projections, exactly oppofite to each other; namely, thofe on the African coaft, from the Canary Ifles to Guiney; and thofe of America, from Guiana to the mouth of the Rio-Janeiro.

It is, therefore, apparent, that the moft ancient lands on the globe are thofe which extend from 200 to 250 leagues on each fide of the two lines above

above deſcribed. Agreeable to this idea, which is founded on the obſervations already made, we find that, in the Old Continent, the moſt ancient countries of Africa are thoſe which ſtretch from the Cape of Good Hope to the Red Sea and Egypt, and are about 500 leagues broad; and, conſequently, that the whole weſtern coaſt of Africa, from Guiney to the Straits of Gibraltar, are new lands. In the ſame manner, if we trace this line through Aſia, and include an equal breadth, we ſhall find, that the moſt ancient countries are, the two Arabia's, Perſia, Georgia, Turcomania, a part of Independent Tartary, Circaſſia, part of Muſcovy, &c.; and, of courſe, that Europe, and perhaps alſo China, and the eaſtern part of Tartary, are comparatively new countries.

In the New Continent, we ſhall likewiſe find, that Terra Magellanica, the eaſtern part of Braſil, of the country of the Amazons, of Guiana, and of Canada, are new lands, when compared with Tucuman, Peru, Terra Firma, the iſlands in the Gulf of Mexico, Florida, the Miſſiſippi, and Mexico. To theſe obſervations may be added two remarkable facts. The Old and New Continents are nearly oppoſite to each other. The Old Continent extends farther north of the equator than ſouth; but the New, farther ſouth than north. The centre of the Old Continent lies in the 16th or 18th degree of north latitude; and the centre of the New Continent lies in the

16th

16th or 18th degree of ſouth latitude, as if they were intended to counterbalance each other. There is another ſingular analogy between the two Continents, though it appears to be chiefly the effect of accident. Both Continents might be divided into two portions, which would be ſurrounded on all ſides by the ſea, except the two ſmall iſthmus's of Suez and Panama.

Theſe general obſervations on the diviſion of the globe are the reſult of an attentive ſurvey. We ſhall not, upon this foundation, erect hypotheſes, or indulge in reaſonings, which might lead to falſe concluſions. But, as the diviſion of the globe has not hitherto been conſidered under this point of view, I ſhall hazard a few remarks. It is not a little ſingular, that the longeſt line which can be drawn upon the two Continents ſhould, at the ſame time, divide them into two equal parts. It is not leſs remarkable, that theſe two lines ſhould commence and terminate at the ſame degrees of latitude, and have the ſame inclination to the equator. Theſe relations may lead to general concluſions, of which we are ſtill ignorant. We ſhall afterwards examine, in detail, the inequalities in the figure of the two Continents, and ſhall here only remark, that the moſt ancient countries ſhould be found in the neighbourhood of the above lines, and ſhould, at the ſame time, have the higheſt elevation; and that the more recent lands ſhould be

be moſt remote from theſe lines, and likewiſe lie lower. Agreeable to this idea, the neweſt countries in America ſhould be the land of the Amazons, Guiana, and Canada. In examining the map of theſe countries, we perceive that they are every where divided by numberleſs lakes and rivers, which is a ſtill ſtronger indication of their recent origin. On the other hand, the regions of Tucuman, Peru and Mexico, are high mountains, and ſituated near the line that divides the continent; circumſtances which ſeem to prove the ſuperior antiquity of theſe countries. Africa is alſo extremely mountainous, and at the ſame time very ancient. In this part of the globe, Egypt, Barbary, and the weſtern coaſt, as far as Senegal, can only be conſidered as new lands. Aſia is perhaps the moſt ancient of all countries, eſpecially Arabia, Perſia, and Tartary. But the inequalities of this great diviſion of the globe, as well as thoſe of Europe, ſhall be treated of in a ſeparate article. We ſhall only remark, in general, that Europe is a new country, as appears from thoſe univerſal traditions concerning migrations of different nations, and the origin of arts and ſciences. It is not long ſince Europe was full of marſhes and foreſts. But, in countries anciently inhabited, there are few woods, lakes, or marſhes, but a great deal of heath and ſhrubs, and many high mountains, with dry and barren tops; for men deſtroy woods, drain marſhes and lakes, and, in proceſs

procefs of time, give an appearance to the face of the earth totally different from that of uninhabited or newly-peopled countries.

A fmall portion of the globe only was known to the ancients. The whole of America, the Artic Circle, Terra Auftralis and Magellanica, and a great part of the interior regions of Africa, were unknown to them. They knew not that the Torrid Zone was inhabited, although they had failed round Africa. About 2200 years ago, Neco King of Egypt furnifhed fome veffels to the Phœnicians, who failed down the Red Sea, doubled the Cape of Good Hope, and the third year after their departure they entered the Mediterranean by the ftraits of Gibraltar*. The ancients, notwithftanding, were totally ignorant of the polarity of the loadftone, although they knew its power of attracting iron; they knew not the caufe of the tides; and they were uncertain whether the ocean furrounded the globe. Some of them, indeed, fufpected that it might be fo; but thefe conjectures were fo ill founded, that none of them ever dreamed of its being poffible to circumnavigate the earth. Magellan, in the year 1519, was the firft who attempted this great voyage; and he accomplifhed it in 1124 days. Francis Drake, in the year 1577, was the fecond; and he performed it in 1056 days. Thomas Cavendifh fet out upon this voyage in 1586, and finifhed it in 777 days.

* See Herodotus, lib. 4.

These

These celebrated navigators were the firſt who gave a phyſical demonſtration of the ſphericity and extent of the circumference of the earth. The ancients, though they travelled much, had no adequate idea of the extent of the globe. They were equally ignorant of the trade-winds, which are ſo uſeful in long voyages. Their limited knowledge in geography, therefore, ſhould not ſurpriſe us, eſpecially when it is conſidered, that, notwithſtanding the advantages derived from the mathematical ſciences, and from the diſcoveries of navigators, many points remain ſtill undetermined, and vaſt regions are yet undiſcovered. Of the countries in the neighbourhood of the ſouth pole, we only know that they exiſt, and that they are ſeparated from the other continents by the ocean*. Much, likewiſe, remains to be diſcovered concerning the lands near the north pole: And it is a ſubject of regret, that, for a century paſt, the ardour for diſcovering new countries has greatly abated. The nations of Europe ſeem, and perhaps they are right, more diſpoſed to increaſe the value of thoſe countries they have already diſcovered, than to acquire new territories.

The diſcovery, however, of the Southern Continent would be a grand object of curioſity, and might be attended with the greateſt advantages. A few of its coaſts have been recogniſed; but thoſe navigators, who have attempted

* Captain Cooke, in his late voyage, has demonſtrated, in the completeſt manner, that no continent exiſts near the ſouth pole.

this

this discovery, have always been prevented from reaching land by large bodies of ice. The thick fogs which infest those seas form another obstacle. But, notwithstanding all these inconveniencies, it is probable, that, by setting out from the Cape of Good Hope at different seasons, part of this new world might still be discovered.

Another method might, perhaps, be attended with more success. To avoid the fogs and the ice, the discovery might be attempted, by departing from Baldivia, or some other port on the coast of Chili, and traversing the south sea under the 50th degree of south latitude. This navigation appears not to be hazardous; and it is probable that it would be attended with the discovery of new lands; for the regions about the south pole, still unknown, are so extensive, that they may be computed to be about a fourth part of the globe; and, consequently, may contain a country as large as the whole of Europe, Asia, and Africa.

While we remain ignorant of this part of the earth, we cannot determine the proportion the surface of the land bears to that of the ocean; from what we do know, it appears that there is more sea than land.

To acquire an idea of the vast quantity of water in the ocean, we must suppose a medium depth, for example, that of 200 fathoms, or the sixth part of a league. Upon this supposition, there is as much water in the ocean as would be sufficient

ſufficient to cover the whole globe to the depth of 600 feet; or, if collected into one maſs, it would form a globe of 60 leagues in diameter.

It is alleged by navigators, that the latitudes near the ſouth pole are much colder than the ſame latitudes towards the north. But this opinion ſeems to have no foundation. It appears to have been adopted from the circumſtance of ice appearing in latitudes where none is found in the northern ſeas. But this effect may be owing to ſome peculiar cauſes. After the month of April, there is no ice on this ſide of 67 or 68 degrees of north latitude; and the ſavages of Acadia and of Canada ſay, that if the ice be not melted in April, it indicates a cold and rainy ſummer. The year 1725 was diſtinguiſhed by an almoſt perpetual rain; and, in April, the ice in the northern ſeas was not only not melted at the 67th degree, but, on the 15th of June, it was found in lat. 41 or 42*.

Great quantities of floating ice appear in the north ſeas, eſpecially at conſiderable diſtances from land. They come from the Tartarean ſea, into that of Nova Zembla and other parts of the Frozen Ocean. I have been aſſured, by people worthy of credit, that an Engliſh Captain, called Manſon, inſtead of ſearching for a paſſage to China between the northern lands, directed his courſe ſtraight to the pole till he arrived within two degrees of it; and that, in this courſe, he

* See l'Hiſt. de l'Acad. anneé 1727.

found

found an open ſea, and no ice; which is a clear proof that the ice is always formed near the land, and never in an extenſive ſea: For, though it ſhould be ſuppoſed, contrary to probability, that the cold was ſo intenſe at the pole as to freeze the ſurface of the ſea, it is ſtill inconceivable how theſe enormous floating maſſes could be formed, without being attached to the land, from which they are again ſeparated by the heat of the ſun. Two veſſels ſent by the Eaſt India Company, in 1739, to diſcover land in the ſouth ſeas, found boards of ice in lat. 47 or 48; but they were not very diſtant from the ſhore, which was in view, though the veſſels could not make their landing good*. Theſe boards of ice muſt have been detached from the lands in the neighbourhood of the ſouth pole; and it may be conjectured that they follow the courſe of ſome large rivers in theſe unknown regions, in the ſame manner as the Oby, the Jeniſca, and other great rivers that fall into the north ſeas, carry down boards of ice, which ſhut up, during the greateſt part of the year, the ſtraits of Waigat, and render the ſea of Tartary, by this courſe, altogether inacceſſible; while, beyond Nova Zembla, and nearer the pole, where there is little land and few rivers, boards of ice are leſs frequent, and the ſea is more navigable. Hence, if any farther attempts be made to find a paſſage to China and Japan by the north ſeas, it

* See on this ſubject a chart by M. Buache, 1739.

it will, perhaps, be neceſſary to keep at a diſtance from the land and the ice, to ſteer directly towards the pole, and to explore the moſt open ſeas, where unqueſtionably there is little or no ice: For it is well known, that ſalt water can take on a greater degree of cold, without freezing, than freſh water after it is congealed; conſequently, the exceſſive cold at the pole may render the ſea colder than ice, without freezing its ſurface. Beſides, at 80 or 82 degrees, the ſea, though mixed with ſnow and freſh water, is never frozen, except near the coaſts. From the united teſtimony of ſeveral navigators, it is apparent, that there is a paſſage from Europe to China by the north ſea: The reaſon why it has ſo often been in vain attempted is obvious. Fear prevented the undertakers from keeping at a ſufficient diſtance from the land, and from approaching the pole, which they probably imagined to be an immenſe rock.

William Barents, however, who, like many others, had run aground in his voyage, never doubted the exiſtence of ſuch a paſſage, or that, if he had kept farther from land, he would have found an open ſea without ice. The Ruſſian navigators ſent by the Czar to reconnoitre the north ſea, relate, that Nova Zembla is not an iſland, but a part of Tartary, and that, to the north of it, there is a free and open ſea. A Dutch voyager affirms, that whales are occaſionally thrown upon the coaſts of Corea and of

 Japan,

Japan, with European harpoons ſticking in their backs. Another Hollander alleges, that he had penetrated to the pole itſelf, and aſſures us, that it was as warm as at Amſterdam in ſummer. One Goulden, an Engliſhman, who had made above thirty voyages to Greenland, related to Charles II. that two Dutchmen, who ſailed along with him, having been unſucceſsful in fiſhing off the coaſt of the Iſle of Edges, reſolved to proceed northward; that, upon their return, fifteen days after, they told him, that they had been at the 89th degree of latitude, where they found no ice, but an open, deep ſea, like that in the Bay of Biſcay; and that they ſhowed him the two ſhips journals in ſupport of what they advanced. In fine, it is related in the Philoſophical Tranſactions, that two navigators, who engaged in the diſcovery of this paſſage, penetrated 300 leagues to the eaſt of Nova Zembla; but, on their arrival, the Eaſt India Company, who thought they had an intereſt in preventing the diſcovery, allowed them not to return that way to Europe*. But the Dutch Eaſt India Company, who believed themſelves intereſted in the diſcovery, having made unſucceſsful attempts on the European ſide, tried to find it by the way of Japan; and they would probably have ſucceeded, if the Emperor of China had not prohibited all ſtrangers from navigating on the coaſts of the lands of Jeſſo. This paſſage, there-

* See Collect. of Voyages to the North, p. 200.

fore, cannot be found but by ſteering directly to the pole beyond Spitzbergen, or rather by keeping the open ſea between Nova Zembla and Spitzbergen, under the 79th degree of latitude. For the reaſons already given, there is no occaſion to dread ice, even under the pole itſelf; for there is no example of a large ſea freezing at a great diſtance from land. The only ſea that freezes totally is the Black Sea, which is narrow, contains little ſalt, and receives from the northern countries a number of rivers, and large boards of ice. If we may credit hiſtorians, this ſea, in the time of the Emperor Copronymus, froze to the depth of 30 cubits. This may be an exaggeration: But that it freezes every winter is certain, while open ſeas, 1000 leagues nearer the pole, never do. This fact can only be explained by the ſuperior ſaltneſs, and the comparatively ſmall quantity of ice-boards which theſe ſeas receive.

Boards of ice, which have been regarded as invincible obſtacles to navigation near the poles, prove only the exiſtence of large rivers in the neighbourhood of the places where they appear. They alſo demonſtrate the exiſtence of vaſt continents, from which theſe rivers derive their ſources; and, therefore, we ought not to be diſcouraged by their appearance: Beſides, very little reflection will convince us, that theſe boards of ice muſt be confined to particular places; that it is impoſſible they ſhould occupy the whole circle in which the ſouthern continent is

ſuppoſed to be contained; and, therefore, if a different route were taken, we have reaſon to hope for ſucceſs. From the deſcription of New Holland, given by Dampier, and others, it is probable, that this part of Terra Auſtralis, which is, perhaps, a part of the ſouthern continent, is a country leſs ancient than what remains to be diſcovered. New Holland lies low; it has neither mountains nor rivers; it is thinly inhabited, and the natives have no induſtry. All theſe circumſtances induce us to think, that the ſavages of New Holland are ſimilar to thoſe of the Amazons, and of Paraguay, in America. In Peru and Mexico, which are the moſt elevated, and, of courſe, the moſt ancient countries of America, the manners of the inhabitants were poliſhed; and they were divided into diſtinct nations, governed by ſovereigns and by laws. Savages, on the contrary, are always found in low and new countries. Hence we may preſume, that, in the elevated and interior parts of the ſouthern continent, from which iſſue thoſe large rivers that carry down boards of ice to the ſea, there are men united by the bonds of ſociety.

The interior parts of Africa are nearly as little known to us as they were to the ancients. They had circumnavigated this immenſe peninſula; but they have neither left us charts nor deſcriptions of its coaſts. Pliny tells us, that this voyage was performed in the days of Alexander the Great; that the wrecks of ſome Spaniſh ſhips were

were found in the Arabian ſea; and that Hanno, the Carthaginian General, had ſailed from Gades to the Arabian gulf, and had written a relation of the voyage. He farther informs us, that, in the days of Cornelius Nepos, one Eudoxus, who had been perſecuted by King Lathurus, was obliged to fly; that he departed from the Arabic gulf, and arrived at Gades; and that, previous to this period, Spain carried on a trade by ſea with Æthiopia *. But, theſe teſtimonies notwithſtanding, we are of opinion, that the ancients never doubled the Cape of Good Hope: Every man conſidered the voyage of the Portugueſe to the Eaſt Indies as a new diſcovery. It will not be incurious to ſee the ſentiments entertained of this ſubject in the ninth century. ‘ In our days, a diſcovery has been ‘ made which was totally unknown to thoſe ‘ who lived before us. No man believed, or ‘ could ſuſpect, that the ſea which reaches from ‘ the Indies to China, had any communication ‘ with the ſea of Syria. But we have lately ‘ found, according to my information, in the ‘ Mediterranean, or ſea of *Roum*, the wreck of ‘ an Arabian ſhip which had been ſtaved to ‘ pieces by a tempeſt. Some of theſe pieces had ‘ been carried, by the wind and the waves, into ‘ the ſea of the Cozars; from thence round to ‘ the Mediterranean, and along that ſea to the ‘ coaſt of Syria. This is a demonſtration that the

* See Plin. Hiſt. Nat. tom. i. lib. 2.

'ocean ſurrounds China and Cila, the extremity 'of Turqueſton, and the country of the Cozars, 'and that, at laſt, it enters by the Straits, and 'waſhes the borders of Syria. The evidence 'ariſes from the conſtruction of the veſſel; for 'there are no ſhips but thoſe of Siraf whoſe 'planks are not nailed. But the veſſel above 'mentioned had all her planks ſtitched together 'in a manner peculiar to the Arabians. But 'all veſſels belonging to the Mediterranean, and 'the coaſt of Syria, have their timbers faſtened 'with nails *.'

I ſhall ſubjoin the remarks added by the tranſlator of this ancient relation:

'Abuziel remarks, as a thing perfectly new, 'that a veſſel had been carried from the Indian 'ſea, and thrown upon the coaſt of Syria. To 'find a paſſage for it into the Mediterranean, 'he ſuppoſes, that there is a great extent of ſea 'beyond China, which communicates with the 'ſea of the Cozars, or of Muſcovia. The ſea 'beyond Cape Current was entirely unknown 'to the Arabians, on account of the extreme 'hazard of navigating it, and becauſe the con'tinent was inhabited by a people ſo barbarous, 'that it was impoſſible either to conquer them, 'or to civilize them by commerce. The Por'tugueſe found not, from the Cape of Good 'Hope to Soffala, any Moors who had an eſta-

* See Les anciennes relationes des voyages faits par terre a la Chine, p. 53.

bliſhed

'lished settlement, like those in all the maritime 'villages as far as China, which was the farthest 'place known to geographers. But they could 'not tell whether the Chinese sea communi- 'cated with that of Barbary by the extremity 'of Africa; they only described it to the coast 'of Zinga or Caffraria. We cannot, therefore, 'hesitate in pronouncing, that the first discovery 'of the passage of this sea, by the Cape of Good 'Hope, was made by the Europeans, under the 'command of Vasca de. Gama, or, at least, a 'few years before he doubled that Cape, if we 'may credit some sea-charts of an older date, 'where the Cape is marked under the name of '*Fronteira da Africa*. Antony Galvan relates, 'upon the testimony of Francisco de Sousa Ta- 'vares, that, in 1528, the Infant Don Ferdi- 'nand shewed him a similar chart from the 'monastery of Acoboca, dated 120 years be- 'fore, copied, perhaps, from that said to be 'in the treasury of St Marc at Venice, on 'which the point of Africa is likewise deline- 'ated, according to the evidence of Ramusio,' &c.

The ignorance of these ages concerning the navigation round Africa is not, perhaps, so singular as the silence of the editor of this ancient relation with regard to the passages in Herodotus, Pliny, &c. which we have quoted, and which proved that the ancients had sailed round Africa.

However this matter ſtands, the coaſts of Africa are now well known. But all the attempts which have been made to penetrate into the interior parts, have not furniſhed us with exact accounts. It would be a great object to go far up the country, by means of the Senegal, or ſome other great river, and eſtabliſh ſettlements. According to every appearance, we ſhould there find a country as rich in precious metals as Peru or Braſil. It is well known, that the rivers of Africa abound in gold duſt; and, as the country is very high and mountainous, and is, beſides, ſituated under the equator, it unqueſtionably contains, as well as America, mines of the heavieſt metals, and ſtones of the hardeſt and moſt compact texture.

The vaſt extent of north and eaſt Tartary is but a late diſcovery. If the Ruſſian charts be juſt, we know the whole coaſt of this part of Aſia; and it appears, that, from the termination of eaſt Tartary to North America, it is an extent not above 400 or 500 leagues. It has even been lately reduced to a much ſhorter ſpace. In the Amſterdam Gazette of 24th January 1747, under the article Peterſburgh, it is alleged, that M. Stolleravoit had diſcovered, beyond Kamtſchatka, one of the North American iſles, and that he had demonſtrated that we might ſail from Ruſſia to America by a very ſhort paſſage. The Jeſuits and other miſſionaries alſo pretended to have known ſavages in Tartary, whom they had catechized in America, which ſuppoſes the paſſage to

to be indeed very ſhort*. Charlevoix would have us believe, that the old and new continents are united in the northern parts. He ſays, that ſome late voyages of the Japaneſe make it probable that the paſſage we have been mentioning is only a bay, beyond which we may paſs, by land, from Aſia to America. But this notion requires confirmation; for it has always been thought, that the continent of the North Pole is probably ſeparated from all other continents, as well as that of the South Pole.

Aſtronomy and navigation have reached ſo high a pitch of perfection, that we may reaſonably hope ſoon to have an exact knowledge of the whole ſurface of the globe. The ancients, who were ignorant of the mariner's compaſs, were able to diſcover a ſmall part of it only. Some pretend that the Arabians invented this inſtrument, and that, by means of it, they carried on trade with India as far as China†. But this notion has always appeared to me to be deſtitute of foundation; for there is not in the Arabian, Turkiſh, or Perſian languages, a word that ſignifies a mariner's compaſs: They uſe the Italian word *boſſola*. Even at this moment, they can neither make compaſſes nor give polarity to the needle. They purchaſe theſe articles from the Europeans. Father Martini alleges, that the Chineſe have been acquainted with the compaſs theſe

* See Charlevoix, tom. iii. p. 30.

† See l'Abregé de l'hiſt. des Sarazins de Bergeron, p. 119.

3000

3000 years*. If theſe facts be true, how ſhould it happen that they have made ſo little uſe of this inſtrument? Why, in their voyage to Cochinchina, did they take a longer courſe than was neceſſary? Why did they always limit themſelves to the ſame expeditions, the longeſt of which was to Java and Sumatra? And why did they not diſcover, before the Europeans, a vaſt variety of iſlands and of fertile countries in their own neighbourhood, if they poſſeſſed the art of navigating in the open ſeas? It was but a few years after the diſcovery of this wonderful quality of the loadſtone, that the Portugueſe doubled the Cape of Good Hope, and traverſed the African and Indian oceans, and that Chriſtopher Columbus ſailed to America.

It was not difficult to conjecture, that immenſe regions exiſted in the weſtern part of the globe; for, on computing what was known of it, namely, the diſtance from Spain to China, and attending to the revolution of the earth, or of the heavens, it was eaſy to perceive, that a greater extent lay to the weſt than what had been already diſcovered on the eaſt. That the ancients found not the new world, was not owing to a deficiency in aſtronomical ſcience, but ſolely to their ignorance of the compaſs. The paſſages of Plato and of Ariſtotle, which mention countries far beyond the Pillars of Hercules, ſeem to indicate that ſome mariners had been driven by a tempeſt

* See hiſt. Sinica, p. 106.

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on the coaſt of America, from which they had returned with infinite labour. But, ſuppoſing the ancients to have been thoroughly convinced, from the relations of voyagers, that ſuch a continent exiſted, being ignorant of the compaſs, they could not poſſibly derive any advantage from ſuch conviction.

I acknowledge, that it is not abſolutely impoſſible for reſolute men, with no other guide than the ſtars, to ſail in open ſeas. The ancients were in poſſeſſion of the Aſtrolabe. They might take their departure from France or Spain, and ſail to the weſt by always keeping the polar ſtar on their right hand; and, by frequent ſoundings, they might keep nearly in the ſame latitude. It was unqueſtionably by keeping the pole-ſtar on their left, that the Carthaginians mentioned by Ariſtotle were enabled to return from thoſe diſtant regions. But it will ſtill be allowed, that a voyage of this kind muſt have been regarded as a raſh and hazardous enterprize. We ought not, therefore, to be ſurpriſed, that the ancients never conceived ſuch a project.

Before the expedition of Columbus, the Azores, the Canaries, and Madeira, had been diſcovered. It had been remarked, that, when the weſt winds continued long to blow, the ſea threw upon the coaſts of theſe iſlands pieces of ſtrange wood, canes of an unknown ſpecies, and even dead bodies, which, by ſeveral marks, were known to be neither Europeans nor Africans*.

* See Charlevoix, tom. i. p. 66.

Columbus

Columbus himſelf remarked, that, on the weſt coaſts, certain winds blew for ſome days, which he was perſuaded proceeded from land. But, though he poſſeſſed all theſe advantages over the ancients, and likewiſe the compaſs, the difficulties to be encountered were ſo great, that nothing leſs than ſucceſs could have juſtified the enterpriſe. Suppoſe, for a moment, that the continent of America had been 1000 or 1500 leagues more diſtant, a circumſtance which Columbus could not foreſee, he never would have arrived, and perhaps this vaſt country might ſtill have remained undiſcovered. This conjecture receives additional force, when it is conſidered, that Columbus, though the ableſt navigator of his age, was ſeized with terror and aſtoniſhment in his ſecond voyage to the New World: As, in his firſt voyage, he found nothing but iſlands, he directed his courſe more to the ſouth in queſt of a continent; but found himſelf ſtopped by currents, the great extent of which, and their uniform oppoſition to his courſe, obliged him to direct his ſearch more to the weſt. He imagined, that it was not currents which prevented him from advancing to the ſouth, but that the ſea was riſing to the heavens, and that both perhaps touched each other in the ſouthern parts: Thus, in great undertakings, the moſt trifling difficulty may ſometimes turn a man's brain, and extinguiſh his courage.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE VII.

Of the Formation of Strata, or Beds, in the Earth.

WE have demonſtrated, in the firſt article, that the earth, in conſequence of the mutual attraction between the particles of matter, and of the centrifugal force that reſults from its diurnal revolution, muſt have aſſumed the figure of a ſpheroid, the two diameters of which differ about a 230th part; and that nothing but the changes made on the earth's ſurface, by the motions of the air and of the waters, could augment this difference, in the manner alleged by thoſe who meaſured a degree under the equator, and another within the polar circle. This figure of the earth, which agrees ſo well with the laws of hydroſtatics and with our theory, indicates

cates that, at the time it aſſumed its figure, it was in a ſtate of fluidity. We have alſo proved, that the projectile motion, and the motion of rotation, were impreſſed at the ſame time, and by the ſame impulſe. It will more readily be admitted, that the earth was originally in a ſtate of liquefaction, when it is conſidered, that the greateſt part of the materials of which this globe is compoſed are either vitrifications, or vitrifiable by fire. The impoſſibility of rendering the earth fluid by the operation of waters confirms this hypotheſis; becauſe there is infinitely more earth than water, and the water is not able to diſſolve ſand, rocks, and hard minerals.

It is, therefore, evident, that the earth aſſumed its figure when in a fluid ſtate: And, to purſue our theory, it is natural to think, that the earth, when it iſſued from the ſun, had no other form but that of a torrent of melted and inflamed matter; that this torrent, by the mutual attraction of its parts, aſſumed a globular figure, which its diurnal motion changed into a ſpheroid; that, when the earth cooled, the vapours which were expanded like the tail of a comet, gradually condenſed, fell down in the form of water upon the ſurface, depoſiting, at the ſame time, a ſlimy ſubſtance, mixed with ſulphur and ſalts, part of which was carried, by the motion of the waters, into the perpendicular fiſſures of the ſtrata, and produced metals, and the reſt remained on the ſurface, and gave

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rise to the vegetable mould, which abounds, in different places, with more or less of animal and vegetable particles, whose organization is not obvious to the senses.

Thus the interior parts of the globe were originally composed of vitrified matter; and, I believe, they continue so at present. Above this vitrified matter were placed those bodies which the fire had reduced into the smallest particles, as sands, which are only portions of glass; and, above these, pumice stones, and the scoriæ of melted matter, which gave rise to the different clays. The whole was covered with water to the depth of 500 or 600 feet*, which originated from the condensation of the vapours, when the earth began to cool. This water deposited a stratum of mud, mixed with all those matters that are capable of being sublimed or exhaled by fire; and the air was formed of the most subtile vapours, which, from their levity, rose above the water.

Such was the condition of the earth, when the tides, the winds, and the heat of the sun, began to introduce changes on its surface. The

* This opinion, that the earth was entirely covered with water, corresponds with the sentiments of several ancient philosophers, and likewise with those of many of the fathers of the church. In mundi primordio, aqua in omnem terram stagnabat, says St. John of Damascus, lib. 2. cap 9. Terra erat invisibilis, quia exundabat aqua et operiebat terram; St. Ambrose, lib. 1. cap. 8. Submersa tellus cum esset, faciem ejus, inundante aqua, non erat adspectabilis; St. Basile, Hom. 2. See likewise St. Augustine, lib. i. cap. 12.

diurnal

diurnal motion of the earth, and that of the tides, elevated the waters in the equatorial regions, and neceſſarily tranſported thither great quantities of ſlime, clay, and ſand, and, by thus elevating theſe parts of the earth, they perhaps ſank thoſe under the poles about two leagues, as was formerly remarked: For the waters would eaſily reduce into powder pumice-ſtones, and other ſpungy parts of the vitrified matter upon the ſurface, and, by this means, excavate ſome places, and elevate others, which, in time, would produce iſlands and continents, and all thoſe inequalities on the ſurface, that are more conſiderable towards the equator than the poles. The higheſt mountains lie between the Tropics and the middle of the Temperate Zones, and the loweſt from the polar circles towards the poles. Between the Tropics are the Cordeliers, moſt of the mountains of Mexico and the Brazils, the great and leſſer Atlas, the mountains of the Moon, &c. Beſides, both the land and the ſea have moſt inequalities between the tropics, as is evident from the incredible number of iſlands peculiar to theſe regions.

However independent of my general theory, this hypotheſis, concerning the original ſtate of the globe, may be, I have choſen to refer to it in this article, with a view to ſhow the connection and poſſibility of the ſyſtem endeavoured to be eſtabliſhed in the firſt article. It may only be remarked, that my theory is not oppoſ-

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ed by the facts; that I take the earth nearly as it stands at present; and that I lay hold of none of those suppositions which are often used in reasoning concerning the former condition of the earth. But, as I here offer a new idea upon this subject of the sediments deposited by the waters that, in my opinion, gave rise to the upper stratum of the earth, it will not be improper to exhibit the reasons upon which it is founded.

The vapours exhaled from the earth produce rain, dews, thunder, lightning, and other meteors. These vapours, therefore, are mixed with particles of water, air, sulphur, earth, &c.; and it is the solid earthy particles which constitute the slime or mud under consideration. The purest rain-water deposits a quantity of this mud; and, when a quantity of dew is collected, and allowed to corrupt, it produces a greater proportional quantity of mud, which is fat, unctuous, and of a reddish colour.

The upper stratum of the earth is composed of this mud, mixed with particles of animal and vegetable substances, or rather with particles of stone and sand. It is worthy of remark, that most arable land is reddish, and more or less blended with heterogeneous matters. The particles of stone or of sand found in the upper stratum, are of two kinds; the one is gross and heavy, the other fine, and sometimes impalpable. The gross is detached from the inferior stratum by labouring the ground; or, rather,

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the upper ſtratum, by penetrating the inferior which is compoſed of ſand or gravel, forms what is called *fat*, or *fertile ſand*. The finer ſpecies proceeds from the air, falls down with the dew or rain, and intimately incorporates with the vegetable mould, or upper ſtratum. This laſt is nothing more than the duſt, tranſported by the air, and again depoſited by rain or a moiſt atmoſphere. When the quantity of this mud is great in proportion to the particles of ſtone or ſand, the ſoil is red and fertile; if it be conſiderably mixed with animal and vegetable ſubſtances, it is blackiſh; but if the quantity of mud and of vegetable and animal ſubſtances be ſmall, the ſoil is white and barren; and even when the particles of ſand, ſtone, or chalk, which compoſe theſe barren ſoils, are mixed with a conſiderable quantity of animal and vegetable ſubſtances, they become black and light, but have very little fertility. According, therefore, to the different proportions of theſe three ingredients, the ſoil is more or leſs fertile, and differently coloured.

In order to acquire diſtinct ideas concerning the ſtrata of the earth, we ſhall take for an example the pits at Marly-la-Ville, which are exceedingly deep. This place is ſituated in a high, but flat and fertile country, and its ſtrata lie horizontally. I procured ſpecimens of all theſe ſtrata in their order from M. Dalibard, an eminent botaniſt, and a man of ſcience; and, after having

having proved, with aqua fortis, the nature of the matters they respectively consist of, I arranged them in the following table.

Table of the different beds of earth at Marly-la-Ville, to the depth of 100 feet.

	Feet.	Inch.
1. A free reddish earth, mixed with a large quantity of mud, a little vitrifiable sand, and a greater proportion of calcinable sand, or gravel	13	
2. A free earth mixed with gravel and with more vitrifiable sand	2	6
3. Mud mixed with a large quantity of vitrifiable sand, which made but a small effervescence with aqua fortis - - -	3	
4. Hard marl, which effervesced violently with aqua fortis -	2	
5. A marly stone very hard -	4	
6. Marl in powder, mixed with vitrifiable sand - -	5	
7. Fine vitrifiable sand - -	1	6
8. Marl resembling earth, mixed with a little vitrifiable sand -	3	6
9. Hard marl, in which was found genuine flint - -	3	6
10. Gravel, or marl in powder -	1	
Carried over	39	

		Feet.	Inch.
	Brought over	39	
11.	Eglantine, a hard ringing ſtone, of the grain of marble -	1	6
12.	Marly gravel -	1	6
13.	Marl in the form of hard ſtone, with a fine grain -	1	6
14.	Marl like ſtone, with a coarſer grain - -	1	6
15.	Marl ſtill more groſs -	2	6
16.	Fine vitrifiable ſand, mixed with foſſil ſea-ſhells, which had no cohesion with the ſand, and which ſtill preſerve their natural colours	1	6
17.	Fine gravel, or marl-duſt -	2	
18.	Marl in the form of a hard ſtone	3	6
19.	Marl in the form of coarſe powder	1	6
20.	Hard ſtone, calcinable like marble	1	
21.	A gray vitrifiable ſand, mixed with foſſil ſhells, particularly with oyſters and ſpondyles, which had no coheſion with the ſand, and were not petrified - -	3	
22.	A white vitrifiable ſand, mixed with the ſame ſhells -	2	
23.	A vitrifiable ſand with red and white ſtreaks, and mixed with he ſame ſhells	1	
24.	A coarſer vitrifiable ſand, mixed with the ſame ſhells -	1	
	Carried over	64	

		Feet.	Inch.
	Brought over	64	
25.	A fine, gray, vitrifiable ſand, mixed with the ſame ſhells -	8	6
26.	A fine unctuous ſand, with very few ſhells - -	3	
27.	Brown free ſtone - -	3	
28.	Vitrifiable ſand, ſtriped with red and white - -	4	
29.	A white vitrifiable ſand -	3	6
30.	A reddiſh vitrifiable ſand -	15	
	Total depth of the pit	101	

I formerly mentioned, that I had examined all theſe ſubſtances with aqua fortis, becauſe no other teſt can enable us to make real diſtinctions between earthy bodies of the ſame or of different appearances. Thoſe which effervеſce and ſuddenly diſſolve, on the application of the aqua fortis, are generally calcinable. Thoſe, on the other hand, upon which that acid makes no impreſſion, are vitrifiable.

From this enumeration of ſtrata it is evident, that the land at Mary-la-Ville was formerly covered with the ſea, to the depth of 75 feet, ſince ſhells are found 75 feet below the ſurface. Thoſe ſhells have been collected and depoſited by the water, together with the ſand, which contains them; and the whole ſuperior ſtrata, except the uppermoſt, have been tranſported

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thither by the motion of the waters, and depoſited in the form of ſediment, as is apparent from their horizontal poſition, from the mixture of ſand, ſhells, and marl, which laſt is compoſed of decayed ſhells; and even the upper ſtratum has been almoſt wholly formed of ſlime or mud, with a ſmall mixture of marl.

I have choſen this example, becauſe it is leaſt favourable to my theory; for it appears, at firſt view, difficult to conceive how the mud depoſited by the dew and rains ſhould produce a bed of vegetable ſoil 13 feet thick. But it ought to be remarked, that a ſoil of this thickneſs is rarely to be found, eſpecially in high countries. The general run of ſoils are from three to four feet, and often they exceed not one foot. The ſoil is thickeſt in plains ſurrounded with hills; becauſe the rains daily bring freſh ſupplies from the higher grounds. But, abſtracting from this ſuppoſition, it is plain, that the upper ſtrata formed by the ſea are thick beds of marl. It is natural to think, that the upper ſtratum was originally much thicker, and that, beſide the 13 feet, the ſea would leave a conſiderable quantity of marl. But this marl, being expoſed to the action of the air, of rains, and of the rays of the ſun, would ſoon be reduced into a fine powder. The ſea would not leave this land ſuddenly, but would continue for ſome time occaſionally to cover it, either by the motion of the tides, or by extraordinary

dinary ſwells during great ſtorms; and, of courſe, the upper ſtratum would be mixed with mud, clay, and other ſlimy bodies. After being entirely above the reach of the waves, plants would begin to grow, and the ſoil would conſtantly accumulate, and be tinged with a reddiſh colour by the mud depoſited by dews and rain. Culture would ſtill farther increaſe both its fertility and its thickneſs, and, by allowing the dews and rains to penetrate deeper, would in proceſs of time produce this ſoil of 13 feet.

I ſhall not here examine, whether the reddiſh colour of vegetable mould proceeds from a quantity of iron contained in the mud depoſited by rain and dews. This point, which is of ſome importance, ſhall be diſcuſſed when we come to treat of minerals. It is ſufficient to have given a view of the manner in which the upper ſtratum has been formed: We ſhall now prove, by other examples, that the formation of the interior ſtrata of the earth muſt likewiſe have originated from the operation of the waters.

The upper ſtratum of the globe, ſays Woodward, that magazine for the formation and ſupport of animals and vegetables, is moſtly compoſed of vegetable and animal matter, and is in perpetual fluctuation. All the animals and vegetables which have exiſted ſince the creation, have ſucceſſively extracted from this ſtratum the materials of which their bodies are conſtructed; theſe they again reſtore at their diſſolution, where

they remain prepared for the ſucceſſive formation of new bodies of the ſame ſpecies; the matter which forms one body being naturally diſpoſed to make another of the ſame kind*. In uninhabited countries, where the woods are never cut, nor the herbs brouſed by cattle, the ſoil is conſtantly augmenting. The ſoil, in all woods, even in thoſe which are occaſionally cut, is from 6 to 8 feet thick, and has originated from the leaves, and other decayed parts of vegetables. I have often remarked, that, upon an old Roman way which runs acroſs Burgundy, the ſtones with which it was conſtructed are covered with a black mould of more than a foot thick, and that it nouriſhes trees of a conſiderable ſize. This ſoil could only be produced by the gradual and ſucceſſive deſtruction of vegetable bodies. As vegetables derive more of their ſubſtance from the air and water than from the earth, when they decay, they add more to the ſoil than they extracted from it. Beſides, foreſts collect and retain vapours and moiſture; and, of courſe, in old woods, the ſoil is greatly augmented. But, as animals reſtore much leſs to the earth than they take from it; and, as men conſume vaſt quantities of wood and herbs for fewel and other purpoſes, it follows, that the vegetable ſoil of populous countries muſt continually diminiſh, and become, in time, like thoſe of Arabia Petrea and other eaſtern countries, which were firſt inhabited, where nothing is now

* See Woodward's Eſſay, p. 136.

to

to be found but ſand and ſalts; for the fixed ſalts of plants and of animals remain, while all the other parts volatilize, and are carried off by the air.

Let us next examine the poſition and formation of the interior ſtrata. The earth, ſays Woodward, wherever it has been dug, is compoſed of beds or ſtrata, one above another, in the ſame manner as if they had proceeded from ſucceſſive ſediments depoſited by water. The beds which lie deepeſt are thicker than thoſe immediately above them, and they are gradually thinner till they arrive at the ſurface. Sea-ſhells, teeth, and bones of fiſhes, are found in theſe beds, and not only in thoſe which are ſoft, as chalk, clay, and marl, but even in beds of hard ſtone, marble, &c. Theſe productions of the ſea are incorporated with the ſtone, and, when ſeparated, leave in the ſtone the figure of their ſurface exactly delineated. 'I was abundantly aſſured,' ſays this author, 'that the circumſtances of theſe things in remoter countries were much the ſame with thoſe of ours here: That the ſtone, and other terreſtrial matter, in France, Flanders, Holland, Spain, Italy, Germany, Denmark, Norway, and Sweden, was diſtinguiſhed into ſtrata, or layers, as it is in England: That thoſe ſtrata were divided by parallel fiſſures: That there were incloſed in the ſtone, and all the other denſer kinds of terreſtrial matter, great numbers of ſhells, and 'other

'other productions of the sea; in the same man-
'ner as in that of this island. To be short, by
'the same means I got sufficient intelligence that
'these things were found in like manner in Bar-
'bary, in Egypt, in Guiney, and other parts of
'Africa: In Arabia, Syria, Persia, Malabar,
'China, and other Asiatic provinces: In Ja-
'maica, Barbadoes, Virginia, New England,
'Brasil, Peru, and other parts of America.'
p. 6. 41, 42, &c.

Woodward gives no authority for his assertion, that shells are found in the strata of Peru. But as, in general, his facts are true, I doubt not but his information has been good; and I am persuaded that shells exist in the strata of Peru, as well as every where else. I make this remark on account of a doubt which has been entertained, and which shall afterwards be considered.

In digging a well at Amsterdam, 232 feet deep, the strata were arranged in the following order: 7 feet of vegetable soil; 9 feet of turf; 9 feet of soft clay; 8 feet of sand; 4 of earth; 10 of clay; 4 of earth; 10 of sand; 2 of clay; 4 of small white sand; 5 of dry earth; 1 of soft earth; 14 of sand; 8 of clay mixed with sand; 4 of sand mixed with shells; then 102 feet of clay; and, *lastly*, 31 feet of sand*.

It is uncommon to dig so deep before we find water: But this fact is remarkable in

* See Varenii Geograph. gen. p. 46.

many

many other respects. *1st*, It demonstrates that the sea communicates not with the interior parts of the earth by means of filtration: *2d*, That shells are found 100 feet below the surface in a country extremely low; and, consequently, that the land of Holland has been elevated 100 feet by the sediments of the ocean: *3d*, It may be concluded, that the bed of clay of 102 feet, and the bed of sand, 31 feet of which only had been dug, and whose actual thickness is unknown, lie near to the ancient and original earth that existed before the motion of the waters began to change its surface. In the first article, it was remarked, that, in order to discover the ancient earth, we must dig in the northern, rather than in the southern regions; and in the low and plain, rather than in the elevated countries. These circumstances nearly concurred in the present case. We only wish that the pit had been dug deeper, and that the author had informed us, whether shells, or other sea-bodies, were intermixed with the last strata of clay and of sand. This experiment confirms what was formerly advanced, that the strata are always thicker in proportion to their depth.

The earth consists of parallel and horizontal strata, not in the plains only, but, in general, the hills and mountains have the same structure. The strata of the mountains are even more conspicuous than those of the plains; for the plains are commonly covered with great quantities of sand

ſand and earth brought from the higher grounds by the waters; and, therefore, to find the ancient ſtrata, we muſt dig deeper in the plains than in the mountains.

I have often remarked, that, when the top of a mountain is level, its ſtrata are likewiſe level; but, when the top is not horizontal, the ſtrata follow the direction of its declivity. It has frequently been alleged, that the beds of quarries incline to the eaſt. But in all the chains of rocks which I have examined, I found, that theſe beds always follow the declivity of the hill, whether its direction be eaſt, weſt, ſouth, or north. In raiſing ſtones from the quarry, they are always ſeparated according to their natural poſition; and, if cut in a contrary direction, it is impoſſible to raiſe them of any conſiderable ſize. In all good maſonry, the workmen place the ſtones in the direction in which they lay in the quarry. If laid in an oppoſite poſition, they will ſplit, and be unable to reſiſt the weight of the incumbent building. Hence we may conclude, that ſtones have been originally formed in horizontal beds; that theſe beds have been ſucceſſively accumulated above each other, and have been compoſed of materials, the reſiſtance of which is ſtronger in that than in any other direction.

Every ſtratum, of whatever kind, whether it be horizontal or inclined, is of an equal thickneſs through its whole extent. In the quarries round Paris, the ſtratum of good ſtone is but about

about 18 or 20 inches thick throughout. In the quarries of Burgundy, the ſtone is much thicker. The ſame inequalities take place in marbles. The white and black marbles are thicker than thoſe that are coloured; and there is a hard ſtone with which the people of Burgundy cover their houſes, that exceeds not an inch in thickneſs. Thus, different ſtrata differ much with regard to thickneſs; but each ſtratum uniformly preſerves the ſame thickneſs through its whole extent. This difference is ſo great, that ſtrata are to be found, from leſs than a line, to 1, 10, 20, 30, and 100 feet thick. Both ancient and modern quarries, which are dug horizontally, the ſhafts of mines, and the working of lead, either longitudinally or tranſverſely, prove that ſtrata extend a great way on all ſides. 'It is well known,' as the hiſtorian of the academy obſerves, 'that 'all ſtones have originally been a ſoft paſte, and 'that, as ſtones are almoſt every where to be 'met with, the ſurface of the earth, in all theſe 'places, at leaſt to a certain depth, muſt have 'conſiſted of mud and ſlime. The ſhells found 'in moſt quarries demonſtrate, that this mud 'was an earth diluted by the water of the ſea; 'and, conſequently, that the ſea once covered 'all theſe places; but the ſea could not cover 'them, without, at the ſame time, covering all 'places that were lower, or on the ſame level. 'Now, it is impoſſible that the ſea could cover 'all thoſe places where there are quarries, with-

'out covering the whole surface of the globe. 'If the mountains were then formed, the sea 'must also have covered them; for they are full 'of rocks and quarries, and shells are often 'found in them.

'The sea, then,' continues he, 'covered the 'whole earth; and hence all the beds of stone 'in the plains are horizontal and parallel: The 'fishes, therefore, were the most ancient inha-'bitants of the globe; for neither land-animals 'nor birds could exist. But how has the sea 'retired into those vast basons which it now oc-'cupies? The most natural supposition is, that 'the earth, at least to a certain depth, was not 'all equally solid, but interspersed with vast 'vaults or caverns, the arches of which would 'remain for a time, and at last suddenly fall in. 'The waters would then rush into these hollows, 'fill them up, and leave a part of the surface 'dry, which would become a convenient habi-'tation for land-animals and birds. The shells 'found in quarries strongly confirm this idea; 'for nothing but the bony parts of fishes could 'be preserved so long in the earth. Besides, 'shells commonly lie in vast masses in certain 'parts of the sea, where they remain immove-'able, and form a species of rocks or banks; 'they could not, therefore, follow the sea, which 'suddenly abandoned them. It is for this last 'reason that we find such numbers of fossil-'shells, and so few vestiges of other fishes, which

'is a farther proof that the waters retired with 'rapidity into their present basons. When the 'vaults sunk down, it is very probable that 'mountains were elevated by the same cause, 'and placed upon the surface with rocks and 'quarries already formed. But the beds of these 'quarries could not preserve their original ho-'rizontal position, unless they were raised exact-'ly perpendicular to the surface, which would 'rarely happen. Thus, as we formerly remark-'ed *, the beds of stone in mountains are all 'inclined to the horizon, though they be paral-'lel to each other; for they changed not their 'position with regard to one another, but with 'regard only to the surface of the earth †.'

These parallel beds of earth or of stone, which have been formed by sediments of the ocean, often extend to considerable distances. We even find, in hills separated by valleys, beds of the same materials upon equal levels. This observation has a perfect correspondence with the equal altitudes of opposite hills. The truth of this fact may be easily established; for, in all hills separated by narrow valleys, where stone or marble is found on one hill, we uniformly find these very substances, at the same level, on the opposite hill. I have traced a quarry of marble 12 leagues in length; its breadth is also considerable, though I have not been able to ascertain it with precision. I have often observed,

* See Mem. de l'Acad. ann. 1705, p. 30.
† Ibid. ann. 1716, p. 14.

that

that this bed of marble has every where the same thickness; and that, in hills separated by a valley of 100 feet deep, the same bed always appeared at the same altitude. I am firmly persuaded, that this observation holds with regard to all quarries of stone or of marble which contain shells; but it applies not to beds of freestone. We shall afterwards explain why freestone is not dispersed, like other matters, in horizontal beds, but in blocks, irregular both in form and position.

It has likewise been remarked, that, on the opposite sides of straits of the sea, the strata are the same. This observation is important, and may lead to the discovery of those necks of land, or islands, which have been separated from the Continent. It proves, for example, that England has been separated from France, Spain from Africa, and Sicily from Italy: And it is to be regretted, that the same observation has not been made upon all straits. I have no doubt but it will hold universally. We know not, whether, in the straits of Magellan, the longest we are acquainted with, the same strata are to be found at the same latitude. But we perceive, from very exact charts, that the opposite coasts, which are high, have corresponding angles like those observable in our inland mountains; and this farther proves Terra del Fuego to have been formerly a part of the Continent of America. The same remark has been made with regard to the

strait

ſtrait of Frobiſher; and the iſland of Frieſland appears to have been ſeparated from the continent of Greenland.

The Maldivia iſlands are ſeparated from each other by ſmall branches of the ſea; and, on each ſide of the oppoſite iſlands, the ſtrata of rocks, &c. are the ſame. Theſe iſlands, which, when taken together, extend about 200 leagues in length, were formerly one. They are divided into 13 provinces, called *Cluſters*. Every Cluſter contains a great number of ſmall iſlands, moſt of which will ſoon be under water. It is remarkable, that each of theſe 13 Cluſters is ſurrounded with a chain of rocks of the ſame ſtone, and that there are only three or four ſmall and dangerous openings, through which each of them can be approached. They are all placed in a line, with their ends to each other, and appear evidently to have been once a long mountain crowned with rock *.

Several authors, as Verſtegan, Twine, Sommer, but particularly Campbell, in his deſcription of the county of Kent, give ſtriking proofs that England was formerly joined to France, and that the neck of land that divides them had been carried off by the ſea, which retired, and left a great quantity of low marſhy ground along the ſouthern coaſts of England. As a farther proof of this fact, Dr. Wallis has attempted to ſhow an affinity between the an-

* See Voyag. de Franc. Pyrard, vol. i. p. 107.

cient language of the Gauls and that of the Britains; and he adds ſeveral other remarks, which ſhall be related in the following articles.

If travellers obſerved the figure of lands, the poſition of mountains, and the windings of rivers, they would perceive that oppoſite hills are not only compoſed of the ſame materials at the ſame altitudes, but that they are alſo nearly of an equal height. In all the places where I have travelled, I uniformly remarked this equality in the height of oppoſite hills, eſpecially when they are ſeparated by valleys not above a fourth or a third of a league wide. In valleys of greater width, it is difficult to judge of the height or equality of hills; for, on looking over a level and extenſive plain, it appears to riſe; and diſtant hills ſeem to ſink. But this is not the place to account for theſe phænomena. Beſides, it is not eaſy to determine by the eye the middle of a large valley, unleſs it be traverſed by a river. But, in narrow valleys, the judgment of the eye is more certain. That diſtrict of Burgundy comprehended between Auxerre, Dijon, Autun, and Bar-ſur-ſeine, of which a conſiderable portion is called *le Bailliage de la Montagne*, is one of the moſt elevated parts of France. From one ſide of theſe mountains, which are only of the ſecond order, the water runs to the ocean, and, from the other, to the Mediterranean. There are points of partition, as at Sombernon, Pouilli in Auxois, &c. where the

the water may be turned at pleaſure, either to the ocean or the Mediterranean. This high country is interſected with a number of ſmall valleys, and moſt of them are watered with rivulets. Here I have a thouſand times obſerved the correſponding angles of the hills, and their equality as to height; and I can with confidence affirm, that the ſalient or prominent angles are uniformly oppoſed to the concave ones, and that the heights of the two ſides are nearly the ſame. The farther we advance in this high country, where are the points of partition mentioned above, the mountains riſe the higher. But this height is always the ſame on the oppoſite ſides of the valleys, and the hills riſe or fall equally. The ſame obſervation I have repeatedly made in ſeveral other provinces of France; but they extend not to very high mountains; for theſe are more irregular as to height, and often terminate in unequal points or peaks. In frequently traverſing the Alps and Appennines, I obſerved, that the angles, in effect, correſponded; but that it is almoſt impoſſible to judge, by the eye, concerning the equality or inequality in the heights of oppoſite mountains; becauſe their tops are loſt in the clouds.

The different ſtrata compoſing the earth are not arranged according to their ſpecific gravities. Beds of heavy matter are frequently placed above thoſe of lighter. Solid rocks are often ſupported by beds of earth, clay, or ſand, which

are greatly inferior in ſpecific gravity. This is the caſe with moſt hills, and is eaſily perceived. But, in high mountains, the ſummits are not only rocks, but theſe rocks are ſupported by others; and this ſtructure runs through ſuch an extent of country, where one mountain riſes out of another, that it is difficult to determine whether they are founded on earth, or of what nature this earth is. I have ſeen rocks cut perpendicularly for ſome hundreds of feet; but theſe rocks reſted upon other rocks, without my being able to perceive where they ended. May we not, however, be allowed to conclude from the leſs to the greater? Since the rocks of ſmall mountains, the baſes of which are viſible, reſt upon earths leſs heavy and leſs ſolid than ſtone, is it not reaſonable to think, that earth is likewiſe the baſis of high mountains? Beſides, all I have here advanced tends to prove, that heavy bodies might be accumulated, by the motion of the waters, above light ones; and, if this really takes place in moſt hills, it is probable that it has happened in the manner pointed out by my theory. But, ſhould it be objected, that I had no reaſon to ſuppoſe, that, prior to the formation of mountains, the heavier matter was below the lighter; I anſwer, that I affirm nothing with regard to this article; becauſe there are many ways by which this effect might be produced, whether the heavy matter was above or below, or placed indiſcriminately: For, in order to conceive

conceive how the ſea could firſt form a mountain of clay, and then crown it with rocks, we have only to conſider, that the ſediments might be tranſported from different places, and that they might conſiſt of different materials. The ſea might tranſport from one place ſeveral ſediments of clay, and afterwards depoſit ſediments of ſtony matter; either becauſe all the clay at the bottom, or on the coaſts, was exhauſted, and then the waves would attack the rocks; or, rather, becauſe the firſt ſediments were tranſported from one place, and the laſt from a different one. Beſides, the latter correſponds exactly with experience; for, it is a known fact, that beds of earth, ſtone, gravel, ſand, &c. follow no rule of arrangement, but are placed indifferently, and, as it were, by chance, one above another.

This chance, however, ought to have ſome rules, which can only be diſcovered by analogy and probable conjecture. We have ſeen, that, according to my theory of the formation of the globe, its interior parts ſhould conſiſt of vitrified matter, ſimilar to vitrified ſand, which is only the fragments of glaſs, and of which the clays are the ſcoriæ, or decompoſed parts. Agreeable to this ſuppoſition, the centre of the earth, and even near the ſurface itſelf, ſhould be compoſed of glaſs or vitrified matter, and above this ſhould be found ſand, clay, and other ſcoriæ. Thus, the earth, in its original ſtate,

was a nucleus of glaſs, or of vitrified matter, either compact like glaſs, or divided like ſand, (for that circumſtance depends on the degree of heat applied); above this matter was ſand; and, laſtly, clay. The ſoil, or external covering, was produced from the air, and the mud of water; and it is more or leſs thick according to the ſituation of the ground; more or leſs coloured, according to the different mixtures of mud, ſand, clay, and the parts of decayed animals and vegetables; and more or leſs fertile, according to the abundance or deficiency of theſe parts. To ſhow that this account of the formation of ſand and clay is not altogether imaginary, I ſhall add a few remarks.

I ſuppoſe the earth, in its firſt ſtate, to have been a ſpheroid of compact glaſs, covered with a thin cruſt of pumice-ſtone, and other ſcoriæ of melted matter. The agitation of the air and of the water would ſoon reduce this cruſt of pumice into powder or ſand, which, by uniting into maſſes, would give riſe to free-ſtone and flints, the varieties of which, with regard to colour and denſity, depend upon the different degrees of fineneſs of the ſand that compoſed them.

The conſtituent parts of ſand unite by the application of fire, become very hard, compact, and more or leſs tranſparent, according to the purity of the ſand. But, on the other hand, when expoſed to the action of the air, it exfoliates,

liates, falls down in the form of earth, and may thus produce clays of different kinds. This duſt, which is ſometimes yellow, ſometimes brilliant, and is uſed to dry writings, is nothing elſe than a fine ſand, ſomewhat corrupted, and nearly reduced to an elementary ſtate. Its particles, in time, become ſo attenuated and divided, that they loſe the power of reflecting light, and acquire all the properties of clay. On examining a piece of clay, many of theſe ſhining or talky particles appear; becauſe they have not yet entirely loſt their original form. Sand, therefore, in proceſs of time, may produce clay; and this clay, by a farther diviſion, acquires the qualities of mud or ſlime, a vitrifiable matter of the ſame nature with clay.

This theory is confirmed by daily experience. In waſhing ſand, the water becomes impregnated with a black, ſoft, fatty earth, which is a genuine clay. The mud ſwept from ſtreets paved with free-ſtone, is black and very fat, and, when dried, it diſcovers itſelf to be an earth of the ſame nature with clay. Clay, taken from places where there is neither flint nor free-ſtone, and diluted with water, always precipitates a great quantity of vitrifiable ſand.

But, what clearly demonſtrates the exiſtence of ſand, and even of flint and glaſs, in clay, is, that the re-union of its parts, by the action of fire, reſtores it to its original form. Clay, when heated to the degree of calcination, is covered

with a hard coat of enamel; if its internal parts are not vitrified, they become ſo extremely hard as to reſiſt the file; they ſtrike fire with the hammer, and acquire all the properties of flint: A great degree of heat melts and converts them into real glaſs.

Clay and ſand, therefore, are ſubſtances perfectly analogous, and of the ſame kind. If clay can be condenſed to flint, and even to glaſs, why may not ſand, by reſolution, become clay? Glaſs appears to be the true elementary earth, and all mixed bodies are only glaſs in diſguiſe. Metals, minerals, ſalts, &c. are only a vitrifiable earth: Common ſtone, and other analogous bodies, teſtaceous and cruſtaceous ſhells, &c. are the only ſubſtances which cannot be vitrified, and which ſeem to form a diſtinct claſs. The former, by the action of fire, may be converted into a homogeneous, hard, and tranſparent ſubſtance, without any diminution of its weight, and upon which no farther change can be made. The latter, on the contrary, which conſiſt of more active and volatile principles, calcine in the fire, loſe more than a third of their weight, and reſume the form of ſimple earth, without any other change than the reſolution of their conſtituent parts. If theſe bodies be excepted, which are few in number, and of which the combinations produce few varieties in nature, all other ſubſtances, and particularly clay, may be converted into glaſs, and, conſequently, are only

only glaſs in a decompoſed ſtate. If fire quickly vitrifies theſe ſubſtances, glaſs itſelf, whether ſimple, or in the form of ſand or flint, naturally, but by a ſlow and inſenſible progreſs, reſolves into clay.

In countries where flint is the predominant ſtone, the fields are commonly ſtrewed with its fragments: If the place be uncultivated, and if the flints have remained long expoſed to the air without being moved, their upper ſurface is always white; but the ſurface next the ground preſerves its natural colour, which is very brown. When theſe flints are broken, the whiteneſs appears to be not ſuperficial only, but penetrates more or leſs into their internal parts, and forms a belt, which in ſome is not very deep, but, in others occupies nearly the whole ſtone. This white part is ſomewhat granulated, perfectly opaque, as tender as free-ſtone, and adheres to the tongue like the boles. But the other portion of the flint is ſmooth and poliſhed, has neither thread nor grain, and preſerves its original colour, its tranſparency, and its hardneſs. When this half decompoſed flint is put into a furnace, the white part becomes red like a brick, and the brown part becomes exceedingly white. Why ſhall we conclude, with a famous naturaliſt, that flints of this kind are imperfect, and that they are not old enough to have acquired their perfect ſtate? For why ſhould they be all imperfect? And why ſhould they be uniformly imperfect

imperfect on the side only that is exposed to the air? It is, on the contrary, much more probable, that they are changed from the original state, and partly decomposed, and that they are gradually resolved into clay or bole. If this reasoning should appear to be unsatisfactory, expose to the air the hardest and blackest flint, in less than a year the colour of its surface will be changed; and, if the experiment be farther prosecuted, the flint will be found gradually to lose its hardness, its transparency, and its other specific characters, and make daily approaches to the nature of clay.

Sand undergoes the same changes as flint. Every grain of sand may, perhaps, be considered as a small flint, and every piece of flint as a collection of fine sand cemented together. The first example of the decomposition of sand is exhibited in that shining, but opaque powder, called *mica*, with which clay and slate are always impregnated. The quartz, or perfectly transparent flints, in decomposing, produce fat and soft talks, such as those of Venice and Russia, which are as ductile and vitrifiable as clay; and it appears, that talk is the mean between glass, or transparent flint, and clay; but that the gross and impure flints, in decomposing, are converted into clay without any intermediate state.

Our made glass undergoes the same change; when long exposed to the air, it decomposes, and, as it were, exfupts. At first, it assumes a

number

number of colours, then it exfoliates, and, in handling it, we perceive that many ſhining particles fall off. But, when its decompoſition is farther advanced, it bruiſes between the fingers, and is reduced to a very white, talky, and impalpable powder. Art alſo imitates nature in the decompoſition of glaſs and flint. ' Eſt etiam ' certa methodus, ſolius aquæ communis ope, ' ſilices et arenam in liquorem viſcoſum, eun- ' demque in ſal viride convertendi, et hoc in ole- ' um rubicundum, &c. Solius ignis et aquæ ' ope, ſpeciali experimento, duriſſimos quoſque ' lapides in mucorem reſolvo, qui diſtillans ſub- ' tilem ſpiritum exhibet, et oleum nullis laudi- ' bus prædicabile*.'

Theſe matters ſhall be more fully conſidered when we treat of metals. We ſhall here only add, that the different ſtrata of the globe conſiſt either of materials which may be conſidered as actual vitrifications, or analogous to glaſs, and poſſeſſing its moſt eſſential qualities. It is alſo evident, that, from the decompoſition of glaſs and flint, which daily takes place, there reſults a genuine clay. Hence we may conclude, with a high degree of probability, that ſand and clays have originally been the ſcoriæ of burnt matter, eſpecially when we join to the above circumſtances, the proofs *a priori* which have been employed to ſhow that the earth was formerly in a ſtate of liquefaction occaſioned by the operation of fire.

* Vid. Becher. Phyſ. Subterr.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE VIII.

Of Shells, and other productions of the Sea, found in the Interior Parts of the Earth.

I Have often examined quarries, the ſtones of which were full of ſhells. I have ſeen whole hills compoſed of ſhells, and chains of rocks intermixed with ſhells through their whole extent. The quantity of ſhells, and other productions of the ſea, is, in many places, ſo prodigious, that it is difficult to believe any more of them exiſted in their natural element. It is from this enormous quantity that no doubt remains of the earth's having continued for a very long time under the waters of the ſea. The number of ſea-ſhells found in a foſſil or petrified ſtate is ſo amazing, that were it not for this

this circumstance, we never should have had a proper idea of the surprising quantities of those animals to which the ocean gives birth. We must not, therefore, imagine, like those who talk and reason concerning things they never saw, that shells are only to be found scattered here and there by chance, or in small heaps, like those of oysters thrown from our doors. They appear, on the contrary, in masses like mountains, in banks of 100 or 200 leagues in length. They may often be traced through whole provinces, and in masses of 50 or 60 feet thick. It is only after having learned these facts that a man is entitled to reason on this subject.

The shells of Turenne may serve as a striking example. Let us attend to the description given of them by the historian of the Academy*.

'Though figured stones, and even fossil shells 'found in the bowels of the earth were remarked 'in all ages and nations, they were generally 'considered, even by philosophers, as lusus naturæ; the production of them was ascribed 'to chance, or to some unaccountable and fortuitous train of circumstances; and, of course, 'this wonderful phænomenon added nothing 'to the stock of knowledge. An ignorant potter in Paris†, who knew neither Greek nor 'Latin, about the end of the 16th century, was 'the

* Année 1720, p. 5.

† The correspondence of Palissy's ideas with those of the ancients, is worth remarking. 'Conchulas, arenas, buccinas, 'calculos

'the first man who ventured, in opposition to
'all the learned, to affirm, that fossil shells were
'real shells originally deposited by the sea, in
'those places were they are found; that real
'animals, and particularly fishes, bestowed on fi-
'gured stones their various forms, &c. and he
'boldly defied the whole school of Aristotle to
'invalidate his proofs. His name was Bernard
'Palissy; and he was perhaps the most conspi-
'cuous example of a philosophical genius, un-
'improved by art or learning. His system,
'however, has lain dormant for near a century,
'and even his name has almost been forgot.
'At last, several philosophers revived Palissy's
'ideas; and science has derived great advantage
'from all the fossil shells and figured stones
'which have appeared in the earth: They are
'now, perhaps, become too common, and the
'consequences drawn from them too incon-
'testible.

'But Reaumur's late observations on the sub-
'ject are astonishing. He discovered 'a mass
'below ground of 130,680,000 cubic fathoms
'of shells, either whole or in fragments, with-
'out the least mixture of stone, earth, sand, or
'other foreign matter. Before this remarkable
'instance, fossil shells never appeared in such
'enormous quantities, nor without being mixed

calculos varie infectos, frequenti solo, quibusdam etiam in mon-
'tibus reperiri, certum signum maris alluvione eos coopertos
'locos volunt Herodotus, Plato, Strabo, Seneca, Tertullianus,
'Plutarchus, Ovidius, et alii;' Vide Dausqui, Terra et aqua, p. 7.

'with

‘ with other bodies. This prodigious maſs lies ‘ in Turenne, more than 36 leagues from the ‘ ſea. It is of great ſervice to the peaſants of ‘ that province; they uſe the ſhells for marl in ‘ fertilizing their lands, which would otherwiſe ‘ be perfectly barren.

‘ What the peaſants dig out of the earth, to ‘ the depth of eight or nine feet, conſiſts only ‘ of fragments of ſhells; but theſe fragments are ‘ eaſily recogniſed to be thoſe of real ſhells; for ‘ they ſtill retain their original channels or fur‐ ‘ rows, and have only loſt their luſtre and var‐ ‘ niſh, as moſt ſhells do, after having remained ‘ long under ground. The ſmalleſt fragments ‘ are only duſt; but we know them to be the ‘ duſt of ſhells, becauſe they conſiſt of the very ‘ ſame matter with the larger fragments, and ‘ the entire ſhells, which are ſometimes found. ‘ The ſpecies both of the large fragments and ‘ of the entire ſhells, are eaſily diſtinguiſhable. ‘ Some of theſe ſpecies belong to the coaſt of ‘ Poitou, and others of them to foreign ſhores. ‘ This maſs likewiſe furniſhes corals, and other ‘ productions of the ſea. *Falun* is the name by ‘ which this matter is diſtinguiſhed in that pro‐ ‘ vince; and it is found, wherever the ground ‘ is dug, through an extent of about nine leagues ‘ ſquare. The peaſants never dig deeper than ‘ about 20 feet; becauſe, ſays Reaumur, they ‘ imagine that the expence of labour would ex‐ ‘ ceed the value of the commodity. They might,

‘ however,

' however, dig deeper. But our calculation of
' 130,680,000 cubic fathoms proceeds upon the
' suppofition of only 18 feet deep, and 2200
' fathoms to the league. Every article, there-
' fore, is undervalued, and this mafs of fhells
' muft greatly exceed the above calculation; if
' the quantity be only doubled, this wonderful
' phænomenon will be greatly augmented.

' In phyfical facts, there are little circum-
' ftances, often overlooked by the bulk of man-
' kind, which are, notwithftanding, of great
' confequence in illuftrating the fubject. M. de
' Reaumur has remarked, that all the fragments
' of fhells lie horizontally in the great mafs; from
' which he concludes, that the fragments were
' not depofited at the fame time with the entire
' fhells which originally formed this mafs; be-
' caufe, fays he, the fuperior fhells would, by
' their weight, have broken the inferior ones,
' and the fragments, in that cafe, would necef-
' farily have been difpofed in a thoufand differ-
' ent directions. The whole, therefore, whether
' entire or broken, muft have been gradually
' tranfported thither by the fea, and, of courfe,
' their pofition muft have been horizontal. But,
' though time alone was fufficient to break them
' down, and even to calcine them, it could not
' vary their original pofition. Their tranfport-
' ation muft have been gradual; for, it is im-
' poffible that fuch an immenfe number of fhells
' could be fuddenly crouded together, and yet
' preferve

'preserve a poſition uniformly horizontal; and 'their being aſſembled in one place, demonſtrates 'this place to have once been the bottom of a 'gulf or baſon.

'Though there are many veſtiges of the univerſal deluge which is recorded in ſcripture, yet 'the maſs of ſhells at Turenne could not be an effect of this deluge. Perhaps ſuch an amazing 'maſs is no where to be found, even in the bottom of the ſea. But, ſuppoſing the deluge to 'have forced ſuch a quantity from the ocean, 'they would neceſſarily be carried off with violence and precipitation; and, conſequently, 'could never have been depoſited in the ſame 'poſition. They muſt have been tranſported, 'ſlowly floating in the waves; and, of courſe, 'their accumulation would require a much 'longer time than a year.

'Upon the whole, it is plain, that, either before or after the deluge, the earth, at leaſt ſome 'parts of it, muſt have been in a very different 'ſituation from what it now appears; that the 'ſea and land muſt have had a different arrangement; and that there was formerly a great 'gulf in the middle of Turenne. The changes 'recorded in hiſtory, or even in ancient fable, 'are inconſiderable; but they give us ſome idea 'of what might be produced in a long ſeries of 'ages. M. de Reaumur conjectures, that Turenne was formerly a gulf of the ſea, and that 'the ſhells were tranſported by a current. But

'this is only a mere conjecture, thrown out to 'ſupply the place of a fact as yet imperfectly 'known. Before any certain concluſion can 'be drawn, we muſt have geographical charts of 'all thoſe places where ſhells are found below 'the ſurface of the earth. To accompliſh this, 'much time and numberleſs obſervations are 'requiſite. Science, however, may in time be 'carried thus far.'

An attention to the following circumſtances will leſſen our ſurpriſe at this great collection of ſhells: 1. Shell-fiſh multiply prodigiouſly, and arrive at maturity in a very ſhort time. The multitude of individuals in every ſpecies is a demonſtration of their amazing fertility. In a ſingle day, for example, a maſs of oyſters, of ſeveral fathoms in thickneſs, is often raiſed; the rocks to which they are attached, diminiſh conſiderably in a ſhort time; and ſome banks are entirely exhauſted. The following year, however, furniſhes an equal quantity, and not the ſmalleſt diminution appears. It is even doubted, whether a natural bed of oyſters was ever entirely exhauſted. 2. The ſubſtance of ſhells is analogous to that of ſtone; they are long preſerved when immerſed in ſoft matter; and they eaſily petrify when connected with matter naturally hard; theſe foſſil ſhells, therefore, and other productions of the ſea found on land, being the ſpoils of many ages, muſt neceſſarily have accumulated into large maſſes.

 We

We have already remarked the prodigious quantities of ſhells preſerved in marble, lime-ſtone, chalk, marl, &c. They appear in maſſes like hills or mountains; and they often compoſe more than one half of the bodies in which they are contained. Sometimes they appear entire, and at other times in fragments, but large enough to enable us to diſtinguiſh their reſpective ſpecies. Here our knowledge of this ſubject, derived from obſervation, ſtops. But I go farther, and maintain, that ſhells are the medium employed by nature in the formation of moſt ſtones; that chalk, marl, and lime-ſtone, conſiſt entirely of the duſt or fragments of ſhells; and, conſequently, that the quantity of decompoſed ſhells is infinitely greater than that of thoſe which have been preſerved. Theſe poſitions ſhall be fully eſtabliſhed in the ſection upon minerals; and I ſhall only here exhibit the point of view in which the different ſtrata of the earth ought to be conſidered. The firſt bed, in which nothing of the original ſtructure appears, is compoſed of mud depoſited by dews, rains, and ſnow, and of particles of animal and vegetable ſubſtances. The inferior beds of chalk, marl, lime-ſtone, and marble, are compoſed of the ſpoils of ſhells and other ſea-bodies, mixed occaſionally with entire ſhells or fragments of them. But clay and vitrifiable ſand are the materials which compoſe the internal parts of the globe. Theſe ſubſtances were

vitrified at the time the earth aſſumed its figure, which neceſſarily implies, that the whole was then in a melted ſtate. The different ſpecies of granite, flint, free-ſtone in large maſſes, ſlate, and coal, derive their origin from ſand and clay, and are alſo diſpoſed in beds. But tufa and pumice, free-ſtone and flint in ſmall or detached pieces, cryſtals, metals, pyrites, moſt minerals, ſulphurs, &c.* are matters, the formation of which is recent, when compared with that of marble, calcinable ſtones, chalk, marl, and other ſubſtances that are diſpoſed in horizontal beds, and contain ſhells, or other relics of the ocean.

As the terms I have employed may appear obſcure or ambiguous, it is neceſſary to explain them. By *clays*, I mean not only the white and yellow clays, but likewiſe the blue, the ſoft, the hard, the laminated, &c. which I conſider to be the ſcoriæ of glaſs, or the decompoſitions of glaſs. By *ſand*, I always underſtand vitrifiable ſand; and I comprehend, under this denomination, not only the fine ſand which produces free-ſtone, and which I maintain to be the powder of glaſs, or rather of tufa, but alſo that ſand rubbed off free-ſtone, and the ſtill groſſer kind reſembling ſmall gravel, proceeding from granite and rock-ſtone, and which is brittle, angular, and reddiſh, and generally found in the beds of thoſe rivers which deſcend precipitantly from hills or mountains compoſed of granite or

or common rock. The river Armanſon, which runs by Semur in Auxois, where all the ſtones are of common rock, carries down great quantities of this groſs, rough, and brittle ſand. It is of the ſame nature with rock-ſtone, of which it is only ſmall portions, as calcinable gravels are only particles of free-ſtone. Beſides, rock-ſtone and granite are the ſame ſubſtances; but I have uſed both terms, becauſe they are conſidered by ſome as different ſpecies. The ſame may be remarked of flints and of free-ſtone in large maſſes: Theſe alſo are ſpecies of granite; and I call them flints in large maſſes, becauſe, like calcinable ſtones, they are diſpoſed in beds, and alſo to diſtinguiſh them from flints and free-ſtone in ſmall maſſes, as the round flints and ſand-ſtones, which have no continuation, or are not found in beds of any extent. Theſe are recent productions, and have not the ſame origin as flint and free-ſtone in large maſſes, which form regular and extenſive ſtrata. Under *ſlate* I comprehend the blue, the white, the gray, the reddiſh, and all the plated ſtones. Theſe bodies are generally found below laminated clay, and ſeem to be nothing elſe but clay hardened into thin ſtrata by drying; and this is the reaſon of ſo many cracks or fiſſures remarkable in ſuch ſubſtances. Coal and jet are likewiſe referable to clay, and are found under the laminated clays or ſlate. By *tufa* I mean not only the common pumice which is

 full

full of holes, and has an organized appearance, but all beds of ſtone formed by the ſediments of running waters, all the ſtalactites, incruſtations, and every kind of ſtone that diſſolves by fire. It does not admit of a doubt that all theſe are new ſubſtances, and that they are conſtantly growing. Tufa is only a maſs of ſtony matter, not diſtinguiſhed by regular ſtrata. This matter is commonly found in ſmall hollow cylinders, is regularly ſhaped, formed by rills or percalations at the foot or upon the declivities of hills, and conſiſting of coats of marl or calcareous earth. The cylindric form is the ſpecific character of this kind of tufa, and it is always either oblique or ſtraight, according to the direction of the rills by which it is produced. The extent of theſe ſpurious quarries is inconſiderable, and generally proportioned to the height of the mountains which furniſh the materials of their growth. The intervals between the cylinders of the tufa, by the daily addition of freſh ſtony matter, are at laſt filled up, and the whole aſſumes a compact and ſolid form; but it never acquires the hardneſs of ſtone, and, for that reaſon, is denominated by Agricola, *marga tofacea fiſtuloſa*. In the tufa are often found impreſſions of the leaves of ſuch trees and plants as grow in the neighbourhood; land-ſhells, well preſerved, are likewiſe frequently found in the tufa, but never ſea-ſhells; it is, therefore, a recent production, and ought to be ranked with

ſtalactites,

ſtalactites, incruſtations, &c. All theſe new ſubſtances are a kind of ſpurious ſtones, formed by the waſting of others, but never arrive at the conſiſtence of real petrifaction.

Cryſtal, precious ſtones, every ſtone that has a regular figure, and even flints in ſmall maſſes, and conſiſting of concentric coats, whether found in the perpendicular fiſſures of rocks, or elſewhere, are only exudations, or the concreting juices of flint in large maſſes; they are, therefore, new and ſpurious productions, the genuine ſtalactites of flint or of granite.

Shells are never found in common rock or granite, nor in free-ſtone, although they often appear in vitrifiable ſand, from which free-ſtone derives its origin. This circumſtance ſeems to indicate, that ſand, unleſs when perfectly pure, cannot unite into free-ſtone or granite; and that a mixture of ſhells, or of other heterogeneous bodies, totally prevents it from cementing. I have often examined thoſe ſmall round ſtones, found in beds of ſand which are mixed with ſhells, and never could diſcover in them a ſingle ſhell. Theſe round ſtones are true concretions of free-ſtone, formed in thoſe places where the ſand is pure, and not mixed with heterogeneous matter; which is the reaſon why no larger maſſes are produced.

We formerly remarked, that, at Amſterdam, which is a very low country, ſea-ſhells were found 100 feet below the ſurface, and at Marly-

la-Ville, 6 leagues from Paris, at the depth of 75 feet. They have alſo been found in mines below beds of rock of 50, 100, 200, and even of 1000 feet thick, as is apparent in the Alps and Pyrennees, where ſhells and other ſea-bodies are found in the inferior ſtrata of immenſe rocks, which have been cut through in a perpendicular direction. But to proceed in order: Shells are found in the mountains of Spain, France, and England, in all the marble quarries of Flanders, in the mountains of Gueldres, in all the hills round Paris, in thoſe of Burgundy and Champagne; in a word, in all places where the baſis is not compoſed of free-ſtone or tufa; and, in all theſe places, the ſubſtance of the ſtones conſiſts more of ſhells than of any other matter. By ſhells, I mean not only the remains of ſhell-fiſh, but likewiſe thoſe of cruſtaceous animals, the briſtles of ſea-hedge-hogs, and all the productions of ſea-inſects, as corals, madrepores, aſtroïtes, &c. Any man may be convinced, by the evidence of his own eyes, that, in moſt marbles and calcinable ſtones, the proportion of ſea-bodies is ſo great, as to exceed the matter by which they are united.

But, farther, ſea-bodies are found even on the tops of the higheſt mountains of the Alps; for example, on the top of Mount Cenis, in the mountains of Genes, in the Apennines, and in moſt of the ſtone and marble quarries of Italy. They appear in the ſtones of which the moſt ancient

ancient buildings in Rome are conſtructed, in the mountains of Tirol, in the centre of Italy, on the top of Mount Paterne near Boulogne, in the hills of Pouille, in thoſe of Calabria, in many parts of Germany and of Hungary, and, laſtly, in all the high grounds of Europe*.

In Aſia and Africa, travellers have obſerved ſea-ſhells in ſeveral places; for example, 'upon 'the Caſtravan mountains, above Baruth,' ſays Shaw †, 'where there is a curious bed of whitiſh 'ſtone, but of the ſlate-kind, which contains, in 'every fleak of it, a great number and variety 'of fiſhes. Theſe, for the moſt part, lie ex- 'ceedingly flat and compreſſed, like the foſſil 'fern plants; yet, at the ſame time, they are ſo 'well preſerved, that the ſmalleſt ſtrokes and 'lineaments of their fins, ſcales, and other ſu- 'perficial diverſities, are eaſily diſtinguiſhed.' Between Cairo and Suez, and particularly upon all the hills of Barbary, ſays the ſame author, are many petrified ſhells and echini; moſt of them exactly correſpond with the different ſpecies ſtill exiſting in the Red Sea. As to Europe, petrified fiſhes are to be met with in Switzerland, Germany, the quarry of Oningen, &c.

Foſſil ſhells, ſays M. Bourguet, are to be found in the long chain of mountains ſtretching from Portugal to the moſt eaſterly parts of China, in the valleys of Europe, and in all the

* See Steno, Ray, Woodward, &c.

† See Shaw's Travels, p. 344.

mountains

mountains of Africa and America; and hence, he remarks, we may conclude, that they alſo exiſt in thoſe parts of the globe with which we are ſtill unacquainted.

The iſlands of Europe, of Aſia, and of America, wherever men have had occaſion to dig, whether in the mountains or in the valleys, furniſh many ſpecimens of foſſil ſhells; and this circumſtance demonſtrates, that iſlands are analogous in ſtructure and formation to their neighbouring continents*.

Theſe facts are ſufficient to prove, that foſſil ſhells, petrified fiſhes, and other productions of the ocean, exiſt in great quantities in almoſt every place where proper inveſtigations have been made. 'It is true,' ſays Tancrid Robinſon, 'that ſea-ſhells are diſperſed occaſionally 'on the earth by armies, and by the inhabitants 'of towns and villages. La Loubere relates, in 'his voyage to Siam, that the monkeys of the 'Cape of Good Hope perpetually amuſe themſelves by tranſporting ſhells from the ſhores of 'the ſea to the tops of the mountains. But this 'is no ſolution to the queſtion, why theſe ſhells 'are diſperſed through every climate of the 'earth, or why they are found in the bowels of 'the higheſt mountains, and diſpoſed in beds, 'like thoſe in the bottom of the ocean.'

Upon peruſing an Italian letter, printed at Paris in the year 1746, concerning the changes

* See Lettres philoſoph. ſur la formation des ſels, p. 205.

this

this globe has undergone, I was aſtoniſhed to find a repetition of Loubere's ſentiments. Petrified fiſhes, in the opinion of this writer, are always of rare ſpecies, which were rejected from the Roman tables, becauſe they were not eſteemed to be wholeſome: And as to foſſil ſhells, he ſays, that the pilgrims brought from Syria, in the time of the cruſades, thoſe ſhells peculiar to the Levant, which are now found petrified in France, in Italy, and in other parts of Chriſtendom. Why did he not add, that the monkeys tranſported ſhells to the tops of the higheſt mountains, which never were inhabited by men? This he might have done with great facility, and it would have given an air of credibility to his hypotheſis! How ſhould men, who pretend to philoſophy, differ ſo widely in their opinions? It is not ſufficient, it would appear, to find foſſil ſhells in almoſt every part of the earth where pits have been dug, nor to have quoted the teſtimonies of natural hiſtorians, as theſe authors may, according to certain ſyſtems, have imagined that ſhells exiſted where none were to be found: We ſhall, therefore, to prevent all prejudices of this kind, quote the authority of ſome authors who had no theory to ſupport, and whoſe habits of obſervation could only enable them to recogniſe ſhells that were entire, and in the beſt preſervation. This teſtimony will, perhaps, have greater authority with men who cannot judge of the facts,

facts, nor know the diſtinction between real ſhells and their petrifactions.

Every man may examine with his eyes the banks of ſhells in the hills round Paris, and eſpecially in the ſtone-quarries, as at Chauſſée near Seve, at Iſſy, Paſſy, and other places. A great quantity of lenticular ſtones are to be found at Villers-Cotterets; the rocks are almoſt entirely compoſed of theſe ſtones; and they are irregularly interſperſed with a kind of cement, by which they are united. At Chaumont, the quantity of ſhells is ſo great, that the whole hills, which are pretty high, appear to conſiſt of nothing elſe. The ſame phænomenon is exhibited at Courtagnon near Rheims, where there is a bank of ſhells of about four leagues broad, and the length is ſtill more conſiderable. I mention theſe places, becauſe they are famous, and the ſhells ſtrike the eye of every beholder.

With regard to foreign countries, let us attend to the remarks of travellers.

'In Syria and Phœnicia, in the neighbour-'hood particularly of Latikea, the rocks are of 'a hard chalky ſubſtance, from whence the ad-'jacent city might borrow the name of the '*White Promontory*. The Nakoura, formerly 'called the *Scala Tyriorum*, is of the ſame na-'ture and complexion; both of them including 'a great variety of corals, ſhells, and other re-'mains of the deluge*.'

* See Shaw's Travels, p. 344.

'But

'But fossil shells, and other the like testimo-
'nies of the deluge, are very rare in the moun-
'tains near Sinai, the original menstruum, per-
'haps, of these marbles, being too corrosive to
'preserve them. Yet, at Corondel, where the
'rocks approach nearer to our free-stone, I
'found a few chamæ and pectunculi, and a cu-
'rious echinus of the discoid kind. The ruins
'of the small village at Ain-el-Mousa, and the
'several conveyances we have there for water,
'are all of them full of fossil shells. The old
'walls of Suez, and the remains that are left us
'of its harbour, are likewise of the same ma-
'terials, all of them probably from the same
'quarry. Between Suez and Cairo, likewise,
'and all over the mountains of Lybia, near
'Egypt, every little rising ground and hillock
'discovers great quantities of the echini, as well
'as of the bivalve and turbinated shells, most of
'which exactly correspond with their respective
'families still preserved in the Red Sea *.'

The moving sand in the neighbourhood of Raz Sem, in the kingdom of Barca, covers many palm-trees, echini, and other petrifactions. *Raz Seme* signifies *the head of a fish*, and is the name of what is called the petrified village, where it has been alledged, that men and women, with their children, cattle, furniture, &c. may be seen converted into stone. 'But,' says Mr. Shaw, 'all this is mere fiction, as I learned not only

* Shaw's Travels, p. 444.

'from

'from Mr. Mair, Conſul at Tripoli, who ſent ſe-
'veral people to examine into the fact, but alſo
'from men of credit and learning who had been
'on the ſpot.'

Near the Pyramids Mr. Shaw diſcovered ſome ſtones which had been hewn by workmen, and were mixed with little round bodies like lentils, and ſome of them reſembled barley half peeled. 'Theſe,' he ſays, 'were ſuppoſed to have been 'fragments of victuals left by the workmen, 'and are now petrified. But this account ap-'pears to be very improbable,' &c. Theſe lentils and grains of barley are nothing but petrified ſhells, known to every naturaliſt by the name of lentil-ſtones.

'Many foſſil ſtones,' ſays Miſſon *, 'are 'found in the neighbourhood of Maeſtricht, 'eſpecially near the village of Zichen or Tichen, 'and in the mountain called the *Huns*.

'In the environs of Sienne, near Certaldo, 'are many mountains of ſand filled with differ-'ent kinds of ſhells. Monte-mario, about a 'mile from Rome, is alſo full of them. I have 'remarked them in the Alps, in France, and 'in other places. Orlearius, Steno, Cambden, 'Speed, and many other writers, have related 'the ſame phænomena †.

'The iſland of Cerigo,' ſays Thevenot ‡, 'was called *Porphyris* by the ancients, on ac-

* See Voyage de Miſſon, tom. 3. p. 109.

† Ibid. tom. 2. p. 312.

‡ Voyage de Thevenot, tom. 1. p. 25.

count

'count of the quantities of porphyry found in 'it.' Now, porphyry, as obſerved above, is compoſed of the prickles of the echinus, or ſea-hedge-hog, united by a very hard ſtony cement.

'Oppoſite to Inchené, a village on the eaſt 'bank of the Nile, I found petrified plants 'growing naturally on a piece of ground about 'two leagues in length, and of an inconſiderable 'breadth. This is one of the moſt ſingular 'productions in nature. The plants reſembled 'the white corals which grow in the Red Sea*.'

'There are ſeveral ſpecies of petrifaction on 'Mount Libanus, and, among others, flat ſtones 'which contain the ſkeletons of fiſhes entire, 'and well preſerved; cheſnuts, and ſmall 'branches of coral, of the ſame ſpecies with 'what grows in the Red Sea, are likewiſe found 'on this mountain †.'

'In mount Carmel,' ſays Shaw, 'we gather a 'great many hollow ſtones, lined in their inſides 'with a variety of ſparry matter, which, from 'ſome diſtant reſemblance, are ſaid to be petri-'fied olives, melons, peaches, and other fruit. 'Theſe are commonly beſtowed upon pilgrims, 'not only as curioſities, but as antidotes againſt 'ſeveral diſtempers. The olives, which are '*lapides Judaici*, as they are commonly called, 'have been always looked upon, when diſſolved 'in the juice of lemons, as an approved medi-

* See Voyage de Paul Lucas, tom. 2. p. 380.

† Ibid. tom. 3. p. 326.

'cine

'cine against the stone and gravel *.' These *lapides Judaici* are the points of the echinus.

'M. la Roche, a physician, gave me some 'petrified olives, called *lápides Judaici*, which 'grow in great quantities upon the mountains, 'where are to be found, according to my in-'formation, other stones, which in their inside 'contain perfect representations of the natural 'parts of men and women †. These are the 'hysterolithes.'

'In going from Smyrna to Tauris,' says Tavernier, 'when we came to Tocat, the heat was 'excessive; we therefore left the common road 'to the north of us, and went by the mountains, 'where there are always shade and cool breezes. 'In many places we found snow; and, upon the 'tops of some of these mountains, we saw shells 'resembling those upon the sea-shore, which is 'an extraordinary phænomenon.'

Let us attend to what Olearius says concerning the petrified shells he observed in Persia, and in the rocks where the sepulchres have been cut near the village Pyrmarus.

'Three of us ascended, by mutually assisting 'each other, the most frightful precipices, and 'at last gained the summit, where we found 'four large chambers, with several niches cut 'out of the solid rock: But what struck us most 'was, to find in this vault, on the top of the

* See Shaw's Travels, p. 444.

† Voyag. de Monconys, p. 334.

'mountain,

'mountain, muſcle-ſhells; and in ſome parts 'they appeared in ſuch quantities, that this 'whole rock ſeemed to conſiſt of nothing but 'ſand and ſhells. In returning from Perſia, 'we perceived ſeveral of theſe ſhelly mountains 'upon the coaſts of the Caſpian Sea.'

To theſe authorities many others might be added, were I not apprehenſive of tiring thoſe who need no additional proofs on this ſubject, and who have perceived with their eyes, as I have done, the exiſtence of ſhells in all places where they have been ſearched for.

In France, we find not only the ſhells belonging to our own coaſts, but thoſe which never appeared in our ſeas. Some philoſophers even alledge, that the number of foreign petrified ſhells greatly exceed thoſe of our own climate. But this opinion ſeems not to be well founded; for, independent of ſuch ſhells as lie in the bottom of deep water, and are ſeldom brought up by fiſhers, and, of courſe, are regarded by us as foreigners, though they may exiſt in our ſeas, I find, upon compariſon, that more of the petrified ſhells belong to our own ſhores than to any other. For example, all the pectines, moſt cockles, muſcles, oyſters, trumpet-ſhells, ear-ſhells, limpets, nautili, ſtars, tubulites, corals madrepores, &c. which are found ſo univerſally, are really produced in our ſeas: And, though many ſea-bodies appear which are either foreign or unknown, as the cornu ammonis, the la-

pides Judaici, the large ſcrew, the buccinum, called *abajour*, &c. yet I am convinced, by repeated obſervation, that the number of theſe ſpecies is inconſiderable, when compared with the ſhells which belong to our own coaſts. Beſides, the madrepores, aſtroites, and all thoſe ſea-bodies formed by inſects, conſtitute the baſis of our marbles and lime-ſtone; for the ſhells, however abundant, make but a ſmall part of theſe ſtones, and many of them are produced in our own ſeas, and particularly in the Mediterranean.

The Red Sea produces corals, madrepores, and ſea-plants, more abundantly than any other. The port of Tor furniſhes an amazing quantity. In calm weather, the quantity exhibited is ſo great, that the bottom of the ſea reſembles a foreſt. Some of the branched madrepores riſe from eight to ten feet high. They are alſo very common in different parts of the Mediterranean; and are to be found in all gulfs, iſlands, &c. of every temperate climate, where the ſea is not very deep.

Mr. Peyſſonel was the firſt who diſcovered that coral, madrepores, &c. were not plants, but that they derived their origin from animals. The truth of this diſcovery was long doubted. Some naturaliſts at firſt rejected it with diſdain. But it ſoon gained univerſal aſſent; and every man is now ſatisfied, that what was formerly called ſea-plants, are nothing but hives, or rather lodges, formed by inſects for their own habitation.

habitation. Theſe bodies were originally claſſed with minerals, then with plants, and now they muſt for ever be recogniſed as the genuine operation of animals.

Many ſhell-fiſh inhabit the deepeſt parts of the ocean, and are never thrown upon the coaſts; authors have, therefore, termed them *Pelagiæ*, to diſtinguiſh them from the other kinds, which they call *Littorales*. It is probable that the cornu ammonis, and ſome other ſpecies, found only in a petrified ſtate, belong to the former, and that they have been impregnated with ſtony matter in the very places where they are diſcovered. It is alſo probable, that the ſpecies of ſome animals have been extinguiſhed, and that theſe ſhells may be ranked among their number. The extraordinary foſſil bones found in Siberia, in Canada, in Ireland, and ſeveral other places, ſeem to confirm this conjecture; for no animal has hitherto been diſcovered to whom bones of ſuch enormous ſize could poſſibly belong.

Foſſil ſhells, ſays Woodward, are found from the top to the bottom of quarries, in pits, and in the deepeſt mines of Hungary: And we are informed by Mr. Ray, that they are found in the rocks on the ſhores of Calda, and in Pembrokeſhire, at the depth of 200 fathoms*.

Shells not only appear in a petrified ſtate at great depths, and on the tops of the higheſt mountains, but they are alſo found in their na-

* See Ray's diſcourſes, p. 178.

tural condition, having the colour, lustre, and lightness of sea-shells; so that, to be fully satisfied on this subject, nothing farther is requisite than to compare them with the shells found on the shores of the sea. The slightest examination will convince us, that petrified and fossil shells are precisely the same with those of the ocean; for they are marked with the same furrows and articulations, however minute; and, in the glossopetri and other teeth of fishes, which are sometimes found adhering to the jaw-bone, it is obvious, that the teeth are worn and polished at the extremities, and that they have been used by the living animals.

Fossil shells are almost every where to be met with; and, of those of the same species, some are small, others large, some young, others old, some entire, others imperfect; and sometimes young ones appear adhering to the old.

The shell-fish called *Purpura* has a long tongue the extremity of which is so sharp and osseous, that it pierces the shells of other fishes, in order to extract nourishment from them. Shells pierced in this manner are often found in the bowels of the earth; which is an incontestible proof that they were formerly inhabited by living fishes, and that they existed in the same places with the purpura*.

The obelisks of St. Peter's at Rome, according to John of Latran, were said to have been

* See Woodward, p. 296. 300.

brought

brought from the Egyptian pyramids: They confist of a red granite, which, as formerly remarked, contains no fhells. But the ancient marbles of Africa and Egypt, and the porphyry faid to have been brought from Solomon's temple, and the palaces of the Egyptian kings, and employed in feveral of the Roman buildings, are full of fhells. Red porphyry is compofed of an infinite number of the prickles of that fpecies of echinus called a fea-chefnut; they are placed very near each other, and form the white points of the porphyry. Each of thefe points have a black fpeck in the middle, which is the fection of the longitudinal tube of the prickle of the echinus. At Ficin in Burgundy, three leagues from Dijon, there is a red ftone fo fimilar to porphyry, that it differs only in denfity, not being harder than marble: It is entirely compofed of the points or prickles of the echini, and the ftratum of it is confiderable both in thicknefs and extent. Many excellent pieces of workmanfhip are made of it in this province, and particularly the fteps which lead to the pedeftal of the equeftrian ftatue of Louis le Grand, at Dijon. This fpecies of ftone is alfo found in Montbard in Burgundy; it is fofter than marble; but it contains ftill more prickles of the echini, and a fmaller proportion of red matter. Thus the ancient porphyry of Egypt, and the porphyry of Burgundy, differ only in the degree of hardnefs, and in the quantity of

prickles or points of the echinus contained in them.

With regard to what is called green porphyry, I imagine it to be rather a granite than a porphyry. It is not, like the red porphyry, composed of the prickles of the echinus; and its substance has a greater resemblance to that of common granite. The ancient walls of Volatera in Tuscany have been built of stones in which are many shells, and these walls were erected 2500 years ago*. Most marbles, porphyries, and other stones employed in the buildings of the ancients, contain shells and other productions of the ocean, in the same manner as some of our modern marbles. Hence we may conclude, that, independent of the testimony of holy writ, the earth, before the deluge, was composed of the same materials as at present.

Upon the whole, it is apparent, that petrified shells are found in Europe, in Asia, in Africa, and in every place where proper researches have been made. They are also found in America, in the Brasils, for example, in Tucumana, in Terra Magellanica, and in such vast quantities in the Antilles, that what the inhabitants call lime, which lies immediately below the soil, is nothing but a congeries of shells, corals, madrepores, astroites, and other sea-bodies. These incontestible facts would have led me to conclude, that petrified shells, and other productions of the

* See Steno de solido intra solidum, p. 63.

ocean,

ocean, were to be found through the whole continent of America, and eſpecially in the mountains, as Woodward affirms. But M. de la Condamine, who lived ſeveral years in Peru, aſſures me, that he was never able to diſcover any of them in the Cordeliers, although he had diligently ſearched for them. This phænomenon would indeed be ſingular, and would lead to concluſions ſtill more uncommon. But, I confeſs, the teſtimony of this celebrated obſerver notwithſtanding, I am ſtrongly inclined to believe that there is, in the mountains of Peru, as well as every where elſe, petrified ſhells and other ſea-bodies, although they have not yet been diſcovered. In matters which depend on teſtimony, the poſitive evidence of two witneſſes is a complete proof; but the evidence of ten thouſand witneſſes, who only declare in the negative, that they never obſerved a particular appearance, gives riſe to nothing more than a ſlight doubt. Thus reaſon, joined to the force of a general analogy, obliges me to perſiſt in believing that foſſil ſhells will ſtill be found in the mountains of Peru, eſpecially if they are ſearched for in the ſides, and not on the very ſummits.

The tops of high mountains are generally compoſed of granite, free-ſtone, and other vitrifiable materials, which never contain ſhells. Theſe matters were all formed out of beds of ſand, when they were covered by the ſea. But, when the waters left the mountains, they would

carry off the ſand, and other light bodies, into the plains, and leave nothing on their tops but thoſe beds of rock which had been formed below the ſtratum of ſand. At two, three, or four hundred fathoms below the ſummit of theſe mountains, we often find marbles and other calcinable matters, diſpoſed in parallel beds, and containing ſhells and other ſea-bodies. Hence, if M. de la Condamine examined only the moſt elevated places, which conſiſt of granite, of free-ſtone, or of vitrifiable ſand, it is not ſurpriſing that he did not find foſſil ſhells. But he ought to have explored the lower parts of the Cordeliers, and he would unqueſtionably have diſcovered beds of marble, earth, &c. mixed with ſhells; for ſuch beds have been found in every part of the world that has undergone a proper examination.

But, ſuppoſing it to be a fact, that there are no productions of the ocean in the mountains of Peru, nothing could be concluded from it which could affect our theory. Some parts of the globe, and particularly places of ſuch elevation as the Cordeliers, might never have been covered with the ſea. Theſe mountains, however, would be an ample field for curious obſervation. They would not, in that caſe, conſiſt of parallel beds. Their materials would be very different from all others: They would have no perpendicular fiſſures: The ſtructure of the ſtones and rocks would have no reſemblance to thoſe of other

other countries: *Laſtly*, Theſe mountains would exhibit the ancient ſtructure of the earth before it was changed by the motion of the waters; they would diſcover the primitive ſtate of the globe, its original form, the natural arrangement and connection of its parts. But this notion is ſupported by too ſlender a foundation; and it is more conſonant to the rules of philoſophy to believe that foſſil ſhells exiſt in the mountains of Peru, in the ſame manner as they exiſt every where elſe.

With regard to the poſition of ſhells in beds of earth or of ſtone, let us attend to the following paſſage of Woodward: 'All the ſhells that 'are found in numberleſs ſtrata of earth, and 'rocks, in the higheſt mountains, and in the 'moſt profound quarries and mines, in flint, 'cornelian, agate, &c. and in maſſes of ſulphur, 'marcaſites, and other mineral and metallic bo-'dies, are filled with the ſame ſubſtances that 'compoſe the ſtrata in which they are included, 'and never with any heterogeneous matter;' p. 206. &c.——'We now find in the ſand-'ſtone of all countries, (the ſpecific gravity of 'the ſeveral ſorts whereof is very little different, 'being generally to water as 2½ or $\frac{9}{10}$ to 1) 'only thoſe conchæ, pectines, cochleæ, and 'other ſhells that are nearly of the ſame gra-'vity, viz. 2½ or 2$\frac{5}{8}$ to 1. But there are ordi-'narily found encloſed in it prodigious num-'bers; whereas, of oyſter-ſhells, (which are in

'gravity

'gravity but as about $2\frac{1}{7}$ to 1) of echini, (which 'are but as 2 or $2\frac{1}{7}$ to 1) or the other lighter 'kinds of ſhells, ſcarce one ever appears therein. 'On the contrary, in chalk (which is lighter 'than ſtone, being but as about $2\frac{1}{10}$ to 1) there 'are only found echini, and the other lighter 'ſorts of ſhells;' p. 32, 33.

It muſt here be remarked, that what Woodward ſays with reſpect to ſpecific gravity, is not univerſally true; for ſhells of different ſpecific gravities are often found in the ſame matters; ſhells of cockles, of oyſters, and of echini, for example, are found in the ſame bed of ſtones or of earth. In the cabinet of the French King, there is a cockle petrified in a cornelian, and echini petrified in an agate. Hence the difference in the ſpecific gravity of ſhells has had leſs influence upon their poſition in the ſtrata of the earth than Woodward would have us to believe. The reaſon why the ſhells of the echini, and others of a light texture, abound ſo much in chalk, is owing to this circumſtance, that chalk itſelf is only decompoſed ſhells; thoſe of the echini being lighter and thinner than others, would be moſt eaſily reduced to powder or chalk; and hence beds of chalk could exiſt only in thoſe places where were formerly collected by the ſea great quantities of light ſhells, the deſtruction of which would form that chalk in which we ſtill find ſhells that have reſiſted the operation

operation of time, either in an entire ſtate, or in fragments ſufficient to diſcover their ſpecies.

This ſubject ſhall be more fully treated of in the article concerning Minerals. I ſhall here only obſerve, that Woodward's expreſſions are often too general. He appears to aſſert, that ſhells are found as frequently, and in as great abundance, in flints, cornelians, chalcedonii, ores, and ſulphur, as in other matters. But the fact is, that ſhells are a very rare phænomenon in vitrifiable or purely inflammable ſubſtances; and, in chalk, marl, and marbles, the quantity of them is ſo prodigious, that it is impoſſible to affirm that the lighter and heavier ſhells are uniformly found in ſtrata correſponding to their ſpecific gravities, though, in general, this may be the caſe, oftener than otherwiſe. They are all impregnated with the bodies in which they are immerſed, whether in the horizontal beds, or in the perpendicular fiſſures; becauſe the whole has been affected by the operation of water, though at different times and in different manners. Thoſe found in the horizontal beds of ſtone, marble, &c. have been tranſported and depoſited by the waves of the ſea; and thoſe found in flints, cornelians, and other matters, peculiar to the perpendicular fiſſures, were formed by rills of water impregnated with lapidific or metallic ſubſtances. In both caſes, the matter that fills the ſhells has been in the ſtate of a fine impalpable

pable powder; becaufe every pore of them is completely filled, and the moulds of them are as exact as the impreffions of a feal upon wax.

It is, therefore, apparent, that, in ftone, marble, &c. there are multitudes of fhells fo entire, and fo well preferved, that they may be compared with thofe in our cabinets, or upon the fhores of the fea.

'There being, I fay, befides thefe, fuch vaft 'multitudes of fhells contained in ftone, &c. 'which are entire, fair, and abfolutely free from 'any fuch mineral contagion; which are to be 'matched by others at this day found upon our 'fhores, and which do not differ in any refpect 'from them; being of the fame fize that thofe 'are of, and the fame fhape precifely; of the 'fame fubftance and texture, as confifting of the 'fame peculiar matter, and this conftituted and 'difpofed in the fame manner as is that of their 'refpective fellow-kinds at fea; the tendency 'of the fibres and ftriæ the fame; the compo-'fition of the lamellæ, conftituted by thefe 'fibres, alike in both; the fame veftigia of ten-'dons (by means whereof the animal is faften-'ed and joined to the fhell); in each the fame 'papillæ; the fame futures, and every thing 'elfe, whether within or without the fhell, in 'its cavity, or upon its convexity, in the fub-'ftance, or upon the furface of it. Befides, 'thefe foffil fhells are attended with the ordi-

'nary

'nary accidents of the marine ones, *ex. gr.* they 'sometimes grow to one another, the lesser shells 'being fixed to the larger: They have the bala-'ni, tubuli vermiculares, pearls, and the like, 'still actually growing upon them. And, which 'is very considerable, they are most exactly of 'the same specific gravity with their fellow-kinds 'now upon the shores. Nay farther, they an-'swer all chymical trials in like manner as the 'sea-shells do; their parts, when dissolved, have 'the same appearance to view, the same smell 'and taste*.'

I have often observed, with astonishment, whole mountains, chains of rocks, and extensive quarries, so full of shells, and other sea-bodies, that there was hardly space left for the matters in which they are deposited.

I have seen some arable fields so full of petrified cockles, that they might be picked up by a blind man, others entirely covered with cornu ammonis, and others with cardites; and the more this subject is inquired into, we shall be the more thoroughly convinced, that the number of petrifactions is infinite, and that it was absolutely impossible that all the animals which inhabited these shells could exist at the same time.

I have farther remarked, that the stones of those arable lands which abound with petrified shells in an entire form, well preserved, and detached from all other matter, are frittered down

* Woodward, p. 23, 24.

by

by froſt, which deſtroys ſtones, but has little effect upon petrified ſhells.

Theſe immenſe quantities of petrified ſea-bodies, found in ſo many different places and ſituations, prove, that they could not be tranſported and depoſited by the waters of the deluge; for the greateſt part of them, inſtead of being found in the bowels of the earth, and in ſolid marble at the depth of ſeven or eight hundred feet, muſt have remained on the ſurface.

In all quarries, petrified ſhells form part of the internal ſtructure of the ſtone, the ſurface of which is often covered with ſtalactites, a matter much leſs ancient than the ſtone that contains the ſhells. Another proof that theſe ſhells could not be derived from the deluge is, that the bones, horns, claws, &c. of land-animals, are ſeldom found in a petrified ſtate, and are never incorporated in marble, or other hard ſtones; whereas, if theſe effects had been produced by the deluge, the remains of land-animals would have been found in marbles, as well as thoſe of fiſhes.

To alledge, that the earth was entirely diſſolved at the time of the deluge, is a mere gratuitous ſuppoſition, which required a ſecond miracle in order to give water the power of an univerſal diſſolvent. Beſides, it infers an evident contradiction; for, if water was then an univerſal menſtruum, how could ſhells have been preſerved in the entire ſtate in which we find them?

This

This is an evident demonſtration, that no ſuch diſſolution took place, and that the parallel ſtrata were not formed in an inſtant, but were gradually produced by ſucceſſive ſediments; for, it is apparent to every obſerver, that the diſpoſition of all the materials compoſing the earth has been occaſioned by the operation of water. The only queſtion, therefore, that remains, is, Whether this arrangement of parts was produced all at once, or in a ſucceſſion of time? Now, it has already been ſhown, that it could not poſſibly happen at one time; becauſe the materials are not diſpoſed according to their ſpecific gravities, and becauſe they never ſuffered a general diſſolution. This arrangement, therefore, muſt have originated from ſucceſſive ſediments. Any other cauſe, or particular revolution, would have given riſe to an arrangement totally different. Beſides, particular revolutions, or accidental cauſes, could never have produced a uniform diſpoſition of horizontal and parallel ſtrata throughout the whole globe.

Let us attend to what the hiſtorian of the Academy * has ſaid upon this ſubject.

'The many marks of extenſive inundations,
'and the manner in which mountains muſt be
'conceived to have been produced, demonſtrate,
'that the ſurface of this earth has ſuffered great
'revolutions. However deep we penetrate in-

* Année 1718, p. 3.

' to

'to the globe, we discover nothing but ruins, 'bodies of different kinds amassed and incorporated without any order or apparent design. 'If there be any regularity in the structure of 'the earth, it lies too deep for our researches; 'we must, therefore, confine ourselves to the 'ruins of the external crust, which will be sufficient to occupy the attention of philosophers.

'M. de Jussieu discovered, in the neighbourhood of St. Chaumont, a great quantity of 'slaty or laminated stones, every lamina of 'which was marked with the impression of a 'stem, leaf, or other portion of some plant. 'The impressions of leaves were uniformly 'extended, as if they had been stretched in 'the stones by the hand; a clear demonstration, 'that they had been transported by water, 'which always keeps leaves in that position: 'their situations were various, and sometimes 'they lay across each other.

'It is natural to imagine, that a leaf deposited 'by water upon soft mud, and then covered 'by a similar layer of mud, would impress 'upon the undermost layer the figure of its one 'side, and upon the uppermost the figure of its 'opposite side; and, after these layers hardened 'and petrified, that they would each bear an 'impression of a different side of the leaf. But 'this supposition, however natural, does not 'take place: the two laminæ of stone uni-

'formly

'formerly bear the impreſſion of the ſame ſide 'of the leaf, the one in alto, the other in baſs-'relief. For this obſervation, with regard to 'the figured ſtones of St. Chaumont, we are in-'debted to M. de Juſſieu; but we leave the ex-'plication of it to himſelf, and ſhall proceed to 'remarks of a more general and intereſting na-'ture.

'All the impreſſions on the ſtones of Saint 'Chaumont are of foreign plants, which are 'not to be found in any part of France; they 'are natives either of the Eaſt Indies, or of the 'warmer climates of America. Moſt of them 'belong to the capillary tribes, and they are ge-'nerally particular ſpecies of ferns, the cloſe 'texture of which enables them both to make 'deep impreſſions, and to remain long in a ſtate 'of preſervation. M. Leibnitz was aſtoniſhed 'to find the impreſſions of the leaves of a few 'Eaſt India plants upon ſome ſtones in Ger-'many: In the example under conſideration, 'the wonder is greatly augmented; for, by 'ſome unaccountable deſtination of nature, it 'would appear, that, in all the ſtones of Saint 'Chaumont, not a ſingle impreſſion of a native 'plant is to be found.

'From the number of foſſil ſhells in the 'mountains and quarries exhibited in this coun-'try, as well as in many others, it is apparent, 'that it muſt have formerly been covered with

'the ſea. But how could the American or In-'dian oceans come hither?'*

'To ſolve this and other ſurpriſing phæno-'mena, we may ſuppoſe, with much probabi-'lity, that the ſea originally covered the whole 'globe. But this ſuppoſition will not anſwer; 'becauſe no terreſtrial plants could then exiſt: 'The plants of one country, therefore, could 'only be tranſported to another by great inun-'dations.

'M. de Juſſieu imagines, that, as the bed of 'the ſea is always riſing higher by means of the 'mud and ſand inceſſantly carried into it by the 'rivers, the ſea, at firſt confined by natural dikes, 'might at laſt ſurmount them, and ſpread over 'the land to great diſtances; or, which would 'produce the ſame effect, the dikes might in 'time be rendered ſo thin, by the conſtant ope-'ration of the water, that they would at laſt 'give way. Soon after the formation of the 'earth, when nothing had aſſumed a regular 'or ſettled form, ſudden and prodigious revo-'lutions might then be produced, of which we 'have now no examples, becauſe every thing 'is in ſuch a fixed and permanent ſtate, that 'only ſlow and inconſiderable changes can take 'place: It is for this reaſon that we find a dif-'ficulty in crediting revolutions more ſudden 'and tremendous.

'By

'By ſome of theſe great revolutions the Weſt 'or Eaſt Indian Oceans might have been poured 'in upon Europe: In their journey, they would 'tear up foreign plants, carry them off floating 'on the waves, and gently depoſit them in 'ſhallow places, from which the waters would ſoon evaporate.'

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE IX.

Of the Inequalities upon the Earth's Surface.

THOUGH the inequalities upon the ſurface of the earth may be conſidered as a deformity in its figure, they are abſolutely neceſſary to vegetation and animal life. To be convinced of this fact, we need only conſider what would be the condition of the earth, were its ſurface perfectly ſmooth and regular. Inſtead of thoſe beautiful hills which furniſh abundance of water for ſupporting the verdure of the earth, inſtead of thoſe richly garniſhed fields, where plants and animals find an eaſy and comfortable ſubſiſtence, a dreary ocean would cover the whole globe, and the earth, deprived of all its valuable

valuable and alluring qualities, would be an obſcure abandoned planet, ſuited only for the habitation of fiſhes.

But, independent of moral conſiderations, which ſeldom ought to be employed in natural philoſophy, the ſurface muſt, from a phyſical neceſſity, have been irregular; for, ſuppoſing it to have been originally ſmooth and level, the motion of the waters, ſubterraneous fires, the winds, and other external cauſes, would neceſſarily produce, in time, irregularities ſimilar to thoſe which we now behold.

Next to the elevation of mountains, the depths of the ocean form the greateſt inequalities. This depth is exceedingly diverſified, even at great diſtances from land. In ſome places the ſea is ſaid to be a league in depth; but that is a rare phænomenon; and the moſt common depths are from 60 to 150 fathoms. Gulfs and branches of the ocean which run in upon the land, are ſtill leſs deep; and ſtraits are generally the moſt ſhallow places.

Depths are commonly ſounded by a piece of lead, of 30 or 40 pounds weight, fixed to a ſmall rope. This method anſwers well enough for ordinary depths, but it is liable to error when the depth is very great; for the cord being ſpecifically lighter than water, after much of it has been wound down, the weight of the lead and that of the cord become nearly equal to their bulks of water; then the lead deſcends no more,

 but

but runs off in an oblique line, and floats at the ſame depth. Hence, in ſounding great depths, an iron chain, or ſome body heavier than water, ſhould be employed. It is for want of attention to this circumſtance, that ſome navigators have been led to maintain, that the ſea, in many places, has no bottom.

In general, the depths in open ſeas augment or diminiſh in a pretty regular manner, being commonly deeper the farther from land. But to this remark there are many exceptions; for there are places in the middle of the ſea, as at the *Abrolhos* in the Atlantic, where large ſhelves appear; and there are, in other places, vaſt ſand-banks, well known to the mariners who ſail to the Eaſt Indies.

Along coaſts, the depths are likewiſe very irregular. However, it may be laid down as a certain rule, that the depth is always proportioned to the height of the coaſt: The ſame obſervation applies to rivers.

It is eaſy to meaſure the height of mountains, either geometrically, or by the barometer. This inſtrument determines the height of a mountain pretty exactly, eſpecially in countries where its variation is not conſiderable, as at Peru and other equatorial climates. By one or other of theſe methods, the height of moſt mountains has already been aſcertained; for example, it has been found, that the higheſt mountains of Switzerland exceed Canigau, the moſt elevated of the

the Pyrennees, 1600 fathoms*. Thefe mountains appear to be the higheft in Europe, fince they give rife to a great number of rivers which run into different and very diftant feas, as the Po, which empties itfelf in the Adriatic, the Rhine, which lofes itfelf in the fands of Holland, the Rhone, which falls into the Mediterranean, and the Danube, which runs into the Black Sea. Thefe four rivers, the mouths of which are fo diftant, derive part of their waters from St. Godard and the neighbouring mountains; a clear proof that this place is the moft elevated part of Europe.

Mount Taurus, Imaus, Caucafus, and the mountains of Japan, are higher than any in Europe. The mountains of Africa, as the great Atlas, and the mountains of the Moon, are at leaft equally high with thofe of Afia; and the higheft of all are thofe of South America, and efpecially of Peru, which are 3000 fathoms above the level of the fea. In general, the tropical mountains are more elevated than thofe of the temperate zones, and thofe of the latter are higher than thofe nearer the poles. Thus, the nearer the equator, the greater are the fuperficial inequalities, which, though confiderable with regard to us, are nothing when eftimated in relation to the whole globe. A difference of 3000 fathoms in 3000 leagues diameter, is but a fathom to a league, or a foot to 2200 feet, and, upon a globe

* See Hift. de l'Acad. 1708, p. 24.

of $2\frac{1}{2}$ feet, would not make the 16th part of a French line. Hence this earth, which to us appears to be traverſed and interſected by mountains of an enormous height, and by ſeas of a dreadful depth, is, in relation to its ſize, but ſlightly furrowed with inequalities ſo inconſiderable, that they cannot make any variation upon its general figure.

In continents, the mountains form continued chains; but, in iſlands, they are more interrupted, generally riſe in the form of a cone, or pyramid, and are diſtinguiſhed by the name of peaks. The Peak of Teneriffe, in the Iſland of Fer, is one of the higheſt mountains in the earth; it is nearly a league and a half perpendicular above the level of the ſea. The Peak of St. George in one of the Azores, and the Peak of Adam, in the Iſland of Ceylon, are likewiſe exceedingly high. Theſe peaks are compoſed of rocks, piled above each other; and all of them throw out, from their ſummits, fire, aſhes, bitumen, minerals, and ſtones. Some iſlands, as St. Helena, Aſcenſion Iſle, and moſt of the Canaries and Azores, are only the tops or points of mountains. It is alſo worthy of remark, that the middle of moſt iſlands, promontories, and capes, is the moſt elevated, and that they are generally divided into two parts, by chains of mountains which run in the direction of their greateſt length: In Scotland, for example, the Grampian mountains (Grans-bain) extend from eaſt to weſt, and divide the iſland of Great Britain into

two

two parts: The ſame thing takes place in Sumatra, the Lucca Iſlands, Borneo, Celebes, Cuba, St. Domingo, the peninſulas of Corea and Malaya, &c. Italy is alſo longitudinally traverſed by the Apennines.

Mountains, as mentioned above, are of different heights; the hills are loweſt; then follow the mountains of an ordinary height, which are ſucceeded by a third range ſtill higher. All theſe are commonly covered with trees and plants; but neither of them furniſh ſprings except at their bottoms. In the laſt and higheſt range, we find nothing but ſand, looſe ſtones, flints, and rocks, the tops of which often reach above the clouds. Preciſely at the foot of theſe rocks, are little plains, or hollows, which collect rains and ſnow, and form thoſe ponds, moraſſes, or fountains, from which the rivers derive their ſources *.

The figure of mountains is likewiſe very different. Some conſiſt of long chains of nearly an equal height; others are interſected by deep valleys; the contours of ſome mountains are pretty uniform; thoſe of others are moſt irregular, and ſometimes a detached little mountain appears in the middle of a plain or valley. There are alſo two kinds of plains; ſome occupy the low grounds, and others appear in the mountains. The former are generally divided by ſome large river; but the latter, though their

* See Lettres Philoſophiques ſur la Formation des Sels, &c. p. 198.

extent

extent be confiderable, are dry, or furnifhed with a fmall rill only. The plains in the mountains are often exceedingly high, always of difficult accefs, and form one country above another, as in Auvergne, Savoy, and other elevated provinces. The foil of them is firm, and produces plenty of herbs and odoriferous plants, which make them the fineft pafture-grounds in the world.

The tops of high mountains are compofed of rocks of different elevations, which, when viewed at a diftance, make them refemble the waves of the fea *. This is not the only reafon for our affirming that mountains were formed by the motions of the fea; I only mention it, becaufe it correfponds with every other phænomenon. But the following facts put this point beyond all controverfy: The foffil fhells, and other fea-bodies, every where found in fuch profufion, that they could not poffibly be tranfported from the fea, in its prefent ftate, into continents fo diftant, and depofited at fuch great depths in the bowels of the mountains: The univerfal parallelifm of the different ftrata, an effect which could only be produced by water, and the compofition even of the moft denfe of them, as thofe of ftone and marble, which clearly evinces, that, before their formation, they had been reduced into a fine powder, and precipitated to the bottom in the form of fediments:

* See ibid. p. 196.

The

The exactneſs with which the foſſil ſhells are moulded in the matters in which they are found: The cavities of foſſil ſhells, which are uniformly filled with the ſame ſubſtances that contain them: The correſponding angles of hills and mountains, which nothing could effect but the currents of the ocean: The equality in the heights of oppoſite hills, and the different ſtrata uniformly appearing at the ſame levels: And, laſtly, the direction of mountains, the chains of which extend longitudinally, like the waves of the ſea.

With regard to the depths or hollows on the ſurface of the earth, thoſe of the ocean are unqueſtionably the greateſt. But, as theſe are hid from human view, and can only be diſcovered by ſounding, we ſhall confine ourſelves to thoſe which appear on the dry land, ſuch as deep valleys, precipices found between rocks, abyſſes that preſent themſelves in high mountains, as the abyſs of Mount Ararat, the precipices of the Alps, the valleys of the Pyrennees, &c. Theſe depths are a natural conſequence of the elevation of mountains; they receive the water and earth carried down from the high grounds; their ſoil is generally fertile; and they are full of inhabitants. The precipices among rocks are often occaſioned by a ſudden ſinking of one ſide, the baſe, which generally inclines more one way than another, being loosened by the action of the air, and of froſt, or by the violence of

torrents. But abyſſes, or thoſe enormous precipices that appear on the tops of ſome mountains, and, to the bottom of which, though their circumference be a mile and a half, or three miles round, it is impoſſible to deſcend, have been formed by the operation of fire. They have been the furnaces of ancient volcano's, the matter of which has been exhauſted by exploſions, and the long action of fires that are now extinguiſhed by the defect of combuſtible matter. Of this kind is the abyſs of Mount Ararat, deſcribed by Tournefort. It is ſurrounded with rocks which are black and burnt. The abyſſes of Etna and of Veſuvius will have the ſame appearance after their inflammable materials are exhauſted.

In Plot's hiſtory of the county of Stafford in England, there is an account of a kind of gulf, which was ſounded by a rope of 2600 feet, without finding either water or bottom, the rope being too ſhort *.

The greateſt cavities, and the deepeſt mines, are generally in the mountains, and ſeldom deſcend to the level of the plains. By them we diſcover the internal ſtructure of the mountain only, not that of the globe itſelf.

Beſides, theſe depths are not very conſiderable. Mr. Ray affirms, that the deepeſt mines exceed not half a mile. The mine of Cotteberg, which, in the time of Agricola, was eſteemed to be the

* See Journal des Savans, 1680, p. 12.

deepeſt

deepeſt in the world, was only 2500 feet of perpendicular depth. There are, indeed, holes in particular places, as that mentioned by Plot, or Pool's hole in the county of Derby, the depth of which is probably very great: But none of them bear any ſenſible proportion to the thickneſs of the globe.

If the kings of Egypt, in place of erecting pyramids as monuments of their vanity and riches, had expended equal ſums in making profound excavations into the bowels of the earth, to the depth of perhaps a league, they might have diſcovered ſubſtances which would have recompenſed their labour; they would at leaſt have extended the knowledge of the earth's internal ſtructure, which might have been productive of much utility.

But, let us return to the mountains. The higheſt of them lie between the tropics; and the nearer we approach to the equator, the greater are the inequalities on the earth's ſurface. A ſhort enumeration of mountains and iſlands will be ſufficient to eſtabliſh this point.

In America, the Cordeliers, which are the higheſt mountains in the world, lie preciſely under the equator, and they extend on both ſides a conſiderable way beyond the Tropic circles.

The higheſt mountains of the Moon, of Monomotapa, and the great and little Atlas, in Africa, lie either under or very near the equator.

In

In Aſia, Mount Caucaſus, the chain of which, under different names, runs into China, and through this whole extent, lies nearer the equator than the poles.

In Europe, the Pyrennees, the Alps, and the mountains of Greece, which form one chain, are ſtill leſs diſtant from the equator than the pole.

Theſe chains of mountains, of which we have given an enumeration, are higher, and of greater extent, both in length and in breadth, than thoſe of more northern countries. With regard to their direction, the Alps form a continued chain which runs acroſs the whole Continent from Spain to China. They commence on the ſea-coaſt of Galicia, join the Pyrennees, traverſe France, by Vivares and Auvergne, run through Italy, and ſtretch into Germany, above Dalmatia, until they reach Macedonia; from thence they join the mountains of Armenia, the Caucaſus, the Taurus, the Imaus, and at laſt terminate on the coaſt of Tartary. Mount Atlas, in the ſame manner, traverſes the whole Continent of Africa, from the kingdom of Fez to the ſtraits of the Red Sea. The mountains of the Moon have likewiſe the ſame direction.

But the mountains of America have an oppoſite direction. The vaſt chains of Cordeliers, and other mountains, run more from ſouth to north than from eaſt to weſt.

What

What we have now remarked concerning the greateſt elevations of the land, applies equally to the greateſt depths of the ſea. The moſt extenſive and deepeſt ſeas lie nearer the equator than the poles. From theſe united obſervations, the truth of our general poſition, that the greateſt inequalities of the globe are to be found in the equatorial regions, is ſufficiently eſtabliſhed. Theſe irregularities on the ſurface of the earth give riſe to a number of curious phænomena. Between the Indus and the Ganges, for example, there is a large peninſula, through the middle of which runs a chain of high mountains, called the *Gate*, which extends from north to ſouth, from the extremity of Mount Caucaſus to Cape Comorin. One ſide of this peninſula forms the coaſt of Malabar, the other that of Coromandel. On the Malabar ſide, between the chain of mountains and the ſea, the ſeaſon of ſummer is from September to April; and, during theſe months, the ſky is ſerene, and no rain falls. But on the Coromandel coaſt, which lies on the other ſide of the mountains, this very period is their winter, and the rains fall in torrents. This reverſe of ſummer and winter happens, in ſome places, no farther diſtant than 20 leagues; ſo that, by croſſing the mountains, a man has it in his power to change ſeaſons. The ſame thing, it is ſaid, takes place at Cape Razalgate in Arabia, and even in Jamaica, which is divided from eaſt to weſt by a chain of mountains. On the ſouth ſide

side of these mountains, the plantations enjoy the warmth of summer, while those on the north suffer all the rigours of winter. Peru, which is situated under the line, and extends about 1000 leagues toward the south, is divided into three long and narrow portions, called by the inhabitants *Lanos*, *Sierras*, and *Andes*. The Lanos, which are the plains, extend along the coast of the South sea; the Sierras are hills interspersed with valleys; and the Andes are the famous Cordeliers, the highest mountains of the world. The Lanos are about 10 leagues broad; the Sierras, in many places, 20 leagues; and the Andes nearly the same, though some parts of them are more, and others less broad. The breadth of these divisions is from east to west, and their length from south to north. This part of the world exhibits the following remarkable appearances: 1st, Along the whole coast of the Lanos, a south-west wind almost constantly blows, which is contrary to the ordinary direction of the wind in the Torrid Zone. 2d, In the Lanos, it never rains or thunders, though there are plenty of dews. 3d, It rains almost continually at the Andes. 4th, In the Sierras, which lie between the Lanos and the Andes, it rains from September to April.

It was long thought that all high mountains run from west to east, till the contrary direction was discovered in America. But M. Bourget was the first who remarked the surprising regularity

gularity in the ſtructure of theſe great maſſes. After paſſing the Alps thirty times in fourteen different places, the Apennines twice, and making ſeveral tours in the neighbourhood of theſe mountains, and of Mount Jura, he found, that the contours of all mountains have a near reſemblance to the works in regular fortifications. When the direction of a mountain is from weſt to eaſt, all its projections, or advances, ſtretch to the ſouth and north. This amazing regularity is ſo remarkable in the valleys, that a man is apt to imagine he is walking in a covered way. If, for example, a man travels in a valley from north to ſouth, he perceives that the mountain which lies to the right hand makes projections to the eaſt, and that the projections of the oppoſite mountains regard the weſt, in ſuch a manner, that the prominent and concave angles, on each ſide, alternately correſpond with one another. When the valleys are large, the angles of the mountains are leſs acute, becauſe they are more diſtant from each other, and the declivity is not ſo rapid or ſteep. Theſe angles are not perceptible in plains, except when we ſtation ourſelves on the banks of the rivers, which generally occupy the middle of the plains, and whoſe natural windings correſpond to the moſt advanced angles or projections of the mountains. It is aſtoniſhing that ſuch an obvious fact ſhould have remained ſo long unnoticed; for, it is apparent, that, in valleys lined

 with

with opposite mountains, when the declivity of one of the mountains is less rapid than that of the other, the course of the rivers is not in the middle, but nearer to the steepest mountain*.

These general observations might be confirmed by a multitude of facts. The mountains of Switzerland, for example, are steeper on the south side than on the north, and on the west side than on the east. This appearance is obvious in Mount Gemmi, Mount Brisa, and in almost all the other mountains in this country, the highest of which are those which separate Vallesia, and the Grisons of Savoy, from Piedmont and Tirol. These countries are, indeed, a continuation only of the same mountains, the chain of which extends to the Mediterranean; and the Pyrennees are a continuation only of that vast mountain, which commences in Upper Vallesia, whose branches stretch far to the west and south, and preserve, throughout that whole extent, a great height; but, on the north and east sides, they gradually sink into plains, as appears in those extensive countries which are traversed by the Rhine and Danube before they finish their course, while the Rhone descends with rapidity to the south, and empties itself in the Mediterranean. The same observation is exemplified in the mountains of England and of Norway. But the most perfect example is af-

* See Lettres Philosophiques sur la Formation des Sels, p. 18[illegible] 200.

forded

forded by the mountains of Chili and Peru. The Cordeliers are exceedingly ſteep on the weſt ſide; but they have a gradual declivity to the eaſt, and terminate in vaſt plains, which are watered by the greateſt rivers in the world*.

M. Bourguet, to whom we are indebted for the diſcovery of the correſpondence between the angles of mountains, calls this diſcovery *the Key to the Theory of the Earth*. However, he appears not to have perceived its whole importance; for, in his treatiſe on this ſubject, he gives the ſkeleton only of an hypothetical ſyſtem, in which moſt of his concluſions are either falſe or uncertain. The theory that we have delivered reſts upon four principal facts, the truth of which, after examining the proofs that ſupport them, cannot admit of a doubt: the *firſt* is, That the earth, to very conſiderable depths, is every where compoſed of parallel ſtrata of different matters, which were formerly in a fluid or ſoft ſtate: the *ſecond*, That the ſea has, for many ages, covered the whole earth which we now inhabit: the *third*, That the tides and other motions of the waters, produce inequalities in the bottom of the ſea: and the *fourth*, That the figure, and correſponding direction of mountains, have originated from currents in the ocean.

After peruſing the proofs contained in the ſubſequent articles, the reader will be enabled to

* See Phil. Tranſ. Abridg. vol. 6. part 6. p. 158.

determine whether I am right in maintaining, that theſe facts, when firmly eſtabliſhed, will likewiſe aſcertain the general theory of the earth. What has been remarked concerning the formation of mountains needs no farther explication. But, as it may be objected, that I have not accounted for the formation of peaks, or pointed mountains, nor for ſome other particular facts, I ſhall add ſuch obſervations as have occurred upon this ſubject.

I have endeavoured to form a diſtinct and general idea of the manner in which the materials compoſing this earth are arranged, and have reduced the whole to two claſſes. The *firſt* includes all the matters which are diſpoſed in horizontal or regularly inclined beds or ſtrata; and the *ſecond* comprehends all thoſe matters which appear in detached maſſes, in ridges, or in veins, either perpendicular, or irregularly inclined. In the *firſt* claſs I rank ſands, clays, granites, flints, and free-ſtones in large maſſes, pit-coal, ſlates, and likewiſe marls, chalk, calcinable ſtones, marbles, &c. In the *ſecond*, I include metals, minerals, cryſtals, precious ſtones, and flints in ſmall maſſes. Under theſe two claſſes, all the known materials of the earth are comprehended. Thoſe of the firſt claſs owe their origin to ſediments tranſported and depoſited by the waters of the ſea, and ought to be diſtinguiſhed into ſuch as are calcinable by the application of fire, and ſuch as melt, and are

2 convertible

convertible into glaſs. The matters compre-hended under the ſecond claſs are all vitrifiable, with the exception of thoſe called inflammable, or which totally conſume in the fire.

There are, in the firſt claſs, two diſtinct ſpe-cies of ſand; the one, which abounds more than any other matter in the globe, is vitrifiable, or rather conſiſts of fragments of real glaſs: The other, which is leſs in quantity, is calci-nable, and ought to be regarded as the duſt of ſtone, and as differing from gravel only by the groſſneſs of its grains. In general, vitrifiable ſand lies in beds; but they are frequently inter-rupted by maſſes of free-ſtone, of granite, and of flint; and ſometimes theſe ſubſtances appear in banks of a conſiderable extent.

Sea-ſhells are ſeldom found in this ſand, or in vitrifiable bodies; and even thoſe which appear in them are not diſpoſed in beds, but ſcattered, as it were, by chance: I never, for example, found any in free-ſtone. This ſtone, which abounds in certain places, is nothing but ſand united by a cement. It never appears but in countries where vitrifiable ſand is frequent; and the quarries of it are generally in pointed hills, ſandy lands, or interrupted eminences. Theſe quarries may be wrought on all ſides; and, when they appear in large beds, they are more diſtant from each other than thoſe of marble or calcinable ſtones. Blocks of free-ſtone may be cut of all dimenſions; and, though it be diffi-

cult to work, its hardneſs is inconſiderable; for it is eaſily reduced to ſand by friction, except the black points or nails ſometimes found in it, which are ſo hard as to reſiſt the beſt files. Common rock-ſtone, which I conſider as a ſpecies of granite, is vitrifiable, and of a ſimilar nature with free-ſtone; it is only harder, and more firmly cemented. It has likewiſe ſeveral denſe points, which cut the ſhoes of travellers on mountainous grounds. It alſo contains a great number of talky ſpangles; and the whole is ſo hard as not to be worked without great labour.

After narrowly examining theſe hard points found in free-ſtone and granite, I diſcovered that they conſiſt of metallic matter, which has been melted and calcined by a ſtrong fire, and that they have a perfect reſemblance to certain ſubſtances thrown out of volcano's, of which I have ſeen vaſt quantities in Italy. They are called by the inhabitants *Schiarri*. They are black heavy maſſes, upon which neither fire, water, nor the file, can make any impreſſion. This metallic matter is different from lava, the latter being a ſpecies of glaſs; but the former ſeems to partake more of metal than of glaſs. The points in free-ſtone and granite have a great reſemblance to this matter, which is a farther proof that thoſe ſubſtances have formerly been liquified by fire.

On the tops of ſome high mountains, blocks of granite appear in great quantities. The poſitions of theſe blocks are ſo irregular, that they ſeem

ſeem to have been thrown together by accident; and we ſhould be apt to imagine that they had tumbled down from ſome neighbouring height, if the places where they are found were not higher than any neighbouring ground. But their vitrifiable nature, and their angular and ſquare figures, like thoſe of free-ſtone rocks, diſcover theſe ſubſtances to have an uncommon origin. Thus, in large ſtrata of vitrifiable ſand, we find blocks of free-ſtone and granite, the figure and ſituation of which follow not exactly the horizontal poſition of ſtrata. The rains have gradually brought down from the hills and mountains the ſand with which theſe blocks were originally covered, by furrowing and cutting into thoſe intervals that appear between the yolks or nuclei in free-ſtone, in the ſame manner as the hills of Fontainbleau are interſected. Every point of a hill reſembles a nucleus in free-ſtone quarries, and all the intervals have been ſcooped out by the rains, and the ſand they originally contained has been carried down to the valleys. In the ſame manner, the angular blocks of granite on the tops of high mountains were formerly covered and ſurrounded with vitrifiable ſand, which, being gradually carried off by the rains, left the blocks in the poſition in which they happened to be formed. Theſe blocks are generally pointed at the top, and augment in thickneſs towards their baſes; one block often reſts upon another, that upon a third, and ſo on,

leaving irregular intervals between them; and as, in the courſe of time, the ſand which covered the blocks, and filled the intervals, was waſhed down by the rains, there would nothing remain on the tops of high mountains but pointed piles of irregular blocks; and hence the origin of peaks, or mountains ending in ſharp points.

For, let it be ſuppoſed, as may eaſily be proved by the ſea-bodies found in the Alps, that this chain of mountains was formerly covered by the ocean, and that a thick bed of vitrifiable ſand was depoſited upon their tops, which reduced the whole chain to a level country. This bed of ſand would neceſſarily give riſe to large blocks of granite, of free-ſtone, of flint, and of other bodies, the conſiſtence and figure of which originate from ſand, nearly in the ſame manner as ſalts cryſtallize. Theſe blocks, after the ſand which covered them, and filled their interſtices, was carried down to the plains, by rains, torrents, &c. would maintain their original ſtations, remain bare on the tops of the mountains, and conſtitute all thoſe peaks or pointed eminences ſo frequently exhibited by Nature. To the ſame origin muſt be aſcribed thoſe high detached rocks which are found in China and other countries, as in Ireland, where they are diſtinguiſhed by the name of *Devil's ſtones*, and the formation of which, as well as of peaked mountains, has hitherto appeared ſo difficult to explain. The explication, however, which I have given, is ſo

natural,

natural, that it generally occurs to every person, who examines these objects; and, on this occasion, I will set down a passage from father Tartre. 'From Yanchuin-yen we arrived at Hotcheou. Upon the road we remarked a singular phænomenon, namely, rocks of a surprising height, resembling square towers, in the midst of vast plains. I cannot account for this appearance, unless I be allowed to suppose these rocks to have formerly constituted a part of mountains, and that the earth, sand, and other loose parts, had been gradually washed away by the rains, and left rocks bare on all sides. What fortifies this conjecture is, that we saw some of them, the bases of which were still surrounded with earth to a considerable height *.'

The tops of the highest mountains, often for 200 or 300 fathoms, consist of rocks of granite, free-stone, and other hard and vitrifiable substances: Below these, we frequently meet with quarries of marble, or hard calcinable stone, full of fossil shells; as may be seen at the great Chartreuse in Dauphiny, and upon Mount Cenis, where the stones and marbles which contain shells are situated some hundreds of fathoms below the points or peaks of high mountains, though these beds of stone and marble be more than 1000 fathoms above the level of the sea. Thus those mountains which have peaks or points generally

* See Lettres Edifiantes, tome i. p. 135.

consist

confiſt of vitrifiable rocks; and thoſe, the ſummits of which are flat, contain, for the moſt part, marbles, and hard ſtones full of ſea-bodies. The ſame remark holds with regard to hills; for thoſe compoſed of granite or free-ſtone are generally interſected with points, eminences, cavities, and ſmall valleys. But thoſe compoſed of calcinable ſtone are nearly of an equal height, and are only interrupted by larger and more regular valleys, with correſponding angles; and they are crowned with rocks, uniform and level in their poſition.

Though theſe two ſpecies of mountains ſeem to be very different, their figures have been produced by the ſame cauſe, as has already been ſhown: But, it may be remarked, that the calcinable ſtones have ſuffered no change ſince the original formation of the horizontal ſtrata. The vitrifiable ſands, however, may have been changed and interrupted by the ſubſequent production of rocks and angular blocks which take place in ſand-beds. Both ſpecies have fiſſures. Thoſe in calcinable rocks are almoſt always perpendicular; but thoſe of granite and free-ſtone are ſomewhat more irregular in their direction. It is in theſe fiſſures that metals, minerals, cryſtals, ſulphur, and all the ſubſtances of our ſecond claſs, are found. Below the fiſſures, the waters aſſemble, penetrate the earth, and give riſe to the veins of water which every where appear under the ſurface.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE X.

Of Rivers.

I HAVE already remarked, that, in general, the greateſt mountains occupy the middle of continents; that thoſe of a ſmaller kind divide iſlands, peninſulas, and promontories; that, in the Old Continent, the direction of the greateſt chains of mountains is from weſt to eaſt; and that thoſe which run to the north or ſouth are only branches of the principal chains. It will appear on examination, that the greateſt rivers have the ſame direction, and few of them follow the courſe of the branches of mountains. To be convinced of this fact, we have only to run our eye over a common globe; and, beginning with Spain, we ſhall find that the Vigo, the

Douro,

Douro, the Tagus, and the Guadiana, run from east to west, and the Ebro from west to east; and that there is not a river of any considera-tion which runs from south to north, or from north to south, although Spain be almost entire-ly environed by the sea on the northern and southern parts. This remark concerning the rivers of Spain demonstrates, that the direction of the mountains is from west to east; that the southern provinces near the Straits are more ele-vated than the coast of Portugal; that, in the northern parts, the mountains of Galicia, the Asturias, &c. are a continuation only of the Pyrennees; and that this elevation of the coun-try, both in the south and north, is the cause which prevents the rivers from running to the sea in these directions.

In examining the map of France, it is appa-rent that the Rhone is the only river which runs from north to south; and, even near one half of its course, from the mountains to Lyons, is from east to west: But the direction of all the great rivers, as the Loire, the Charente, the Ga-ronne, and even the Seine, is from east to west.

The same observation holds with regard to Germany. The Rhine, like the Rhone, has the greatest part of its course from south to north: But the other large rivers, as the Danube, the Drave, and all the rivers which fall into them, run from west to east, and empty themselves in the Black Sea.

The

The Black Sea, which ſhould rather be regarded as a large lake, is, from eaſt to weſt, nearly three times as long as from ſouth to north; and conſequently its direction is ſimilar to that of the rivers. The ſame remark is applicable to the Mediterranean, which is nearly ſix times longer from eaſt to weſt than from north to ſouth.

The Caſpian, it muſt be acknowledged, according to the chart made by order of the Czar Peter I. extends more from north to ſouth, than from eaſt to weſt. But the ancient charts repreſented it as nearly round, or rather as extending more from eaſt to weſt than in the oppoſite direction. If, however, the lake Aral be conſidered as a part of the Caſpian, from which it is ſeparated by a ſandy plain only, the greateſt extent of this ſea will ſtill be from weſt to eaſt.

The courſe of the Euphrates, of the Perſic gulf, and of almoſt all the rivers of China, is likewiſe from weſt to eaſt. The rivers of the interior parts of Africa obſerve the ſame direction, running either from weſt to eaſt, or from eaſt to weſt. The Nile, and the rivers of Barbary, are the only ones which run from ſouth to north. There are, it is true, large rivers in Aſia, as the Don, the Wolga, &c. which partly run from north to ſouth: But they only obſerve this direction in order to fall into the Black and

and Caſpian ſeas, which are lakes in the interior parts of the country.

We may, therefore, lay it down as a fact, that, in general, the rivers and mediterranean waters of Europe, Aſia, and Africa, run or ſtretch more from eaſt to weſt than from north to ſouth. This is a natural conſequence of the parallel direction of the different chains of mountains. Beſides, the whole continent of Europe and of Aſia is broader from eaſt to weſt than from north to ſouth: For the direction of mountains may be conſidered in two points of view. In a long and narrow continent, like that of South America, which contains only one principal chain of mountains, extending from ſouth to north, the rivers, not being reſtrained by any parallel chain, muſt run in channels perpendicular to the range of theſe mountains, that is, either from eaſt to weſt, or from weſt to eaſt; and this, in fact, is the direction of all the great rivers in America. But though, both in the Old and New Continent, the great rivers run in the ſame direction, this effect is produced by different cauſes. The rivers, in the Old Continent, run from eaſt to weſt, becauſe they are confined by many parallel chains of mountains which ſtretch from weſt to eaſt; but thoſe of America obſerve the ſame direction, becauſe there is only one chain of mountains ſtretching from ſouth to north.

The

The rivers generally occupy the middle of the valleys, or the loweſt ground between two oppoſite hills: If the two hills have nearly an equal declivity, the river runs nearly in the middle between them, whether the intermediate valley be broad or narrow. If, on the contrary, the declivity of one of the hills be greater than that of the other, the river will not occupy the middle of the valley, but will approach to the ſteepeſt hill, in proportion to the ſuperiority of its declivity. In this caſe, the middle of the valley is not the loweſt ground between the two hills, but lies much nearer the ſteepeſt of them; and conſequently the river muſt occupy that ſpace. This obſervation holds univerſally where-ever the difference in declivity is remarkable; and the rivers never recede from the ſteepeſt hills, unleſs, in their courſe, they meet with other hills of equal declivity. In proceſs of time, however, the declivity of the ſteepeſt hill is diminiſhed by the rains, the melting of ſnow, &c. The ſteeper any hill is, it loſes greater quantities of earth, ſand, and gravel, by the operation of rains, and theſe ſubſtances are carried down into the plain with a proportionably greater rapidity, and, of courſe, force the river to change its channel, or, in other words, to retire into a lower part of the valley. It may be added, that, as all rivers occaſionally ſwell, and overflow their banks, they carry off mud and ſand, which they depoſit in different

parts

parts of the valley; and, as ſand and gravel are often accumulated in the channels themſelves, theſe circumſtances make the waters overflow, and alter the direction of their courſe. Nothing, accordingly, is more common, than to find in valleys many old channels in which the river has formerly run, eſpecially when it is rapid, ſubject to frequent inundations, and carries down great quantities of ſand and mud.

In plains, and extenſive valleys, watered by large rivers, the channels of the rivers are commonly the loweſt parts. But the ſurface of the water in the river is ſometimes higher than the adjacent ground. When a river, for inſtance, begins to overflow, it ſoon covers a conſiderable part of the plain; but the banks remain longeſt uncovered by the water. This circumſtance plainly ſhows that the banks of rivers are higher than the neighbouring ground; and that, from the banks to a certain part of the plain, there is a ſmall declivity or ſlope. When, therefore, the water riſes to the margin of the banks, it muſt be higher than the plain. This elevation of the ground on the banks of rivers is occaſioned by mud and ſand being depoſited in the time of inundations. The water, during great ſwells, is always exceedingly foul and muddy: When it begins to overflow, it runs ſlowly over the banks, and, by depoſiting the mud and ſand, it gradually purifies as it advances into the plain: Thus, all the mud, and other ſubſtances, which are

are not carried down by the current, are deposited upon the banks, and gradually elevate them above the reſt of the plain.

Rivers are always wideſt at their mouths, and turn gradually narrower towards their ſources: But it is more worthy of remark, that, in the interior parts of a country, and at great diſtances from the ſea, their courſe is ſtraight, and the frequency of their windings increaſes proportionally as they approach to their termination. I have been informed by M. Fabry, who performed many journeys in the weſtern parts of North America, that travellers, and even the ſavages, form pretty accurate computations of their diſtance from the ſea, by obſerving the courſes of the rivers. If a river ran ſtraight for 15 or 20 leagues, they knew themſelves to be a great way from the coaſt; but, if the ſinuoſities were frequent, they concluded that the ſea was not very diſtant. M. Fabry, when travelling through unknown and uninhabited regions, derived much advantage from this obſervation. Near the ſides of great rivers, the regorging of the water is likewiſe leſs apparent the farther from the ſea, which furniſhes another medium of judging concerning the diſtance: And, as the ſinuoſities multiply the nearer rivers approach to their mouths, it is not ſurpriſing that ſome of them ſhould yield to the preſſure of the water, and give riſe to ſeveral branches or diviſions, before they reach the ſea.

The motion of the water in rivers is very different from the repreſentation given of it by mathematicians. The ſurface, taken from bank to bank, is not level; but the middle of the ſtream is either higher or lower, according to circumſtances, than the water at the ſides. When a river ſwells ſuddenly by the melting of ſnow, or any other cauſe, its rapidity increaſes; and, if its courſe be ſtraight, the middle of the ſtream, where the current is greateſt, riſes and forms a ſenſible convexity. This elevation is ſometimes very conſiderable. M. Hupeau, who meaſured this difference of level between the ſides and the ſtream of the Aveiron, found it to be three feet. This effect muſt always be produced when the rapidity of the current is great; for the quickneſs of the motion, by diminiſhing, or partly preventing the action of gravity, allows not to the water, in the middle of the ſtream, time ſufficient to bring it to a level with that on the ſides, and, therefore, it remains higher. On the other hand, near the mouths, though the current be very rapid, the water near the ſides is commonly more elevated than that of the middle: The river, in this ſituation, has a concave form, the loweſt point of which is the middle of the ſtream. This effect is always produced as far as the influence of the tides is perceptible, which, in large rivers, extends ſometimes to 100 or 200 leagues from the ſea. It is likewiſe a fact well known, that the ſtreams of

rivers

rivers continue their motion a conſiderable way through the waters of the ſea. In this caſe, the water of the river has two oppoſite motions. The middle, or current, precipitates itſelf towards the ſea; but the action of the tide produces a counter current, or regorging, which elevates the water on the ſides, while that in the middle deſcends; and, as all the water muſt be carried down by the current, that on the ſides conſtantly deſcends towards the middle of the ſtream, with a quickneſs proportioned to the elevation it receives from the regorging of the tide.

There are two ſpecies of regorging, or damming up, in rivers: The firſt is that juſt now deſcribed, and is occaſioned by the action of the tide, which not only oppoſes the natural deſcent of the water, but even communicates to it a contrary motion or current: The other is produced by an inactive cauſe, as a projection of the land, an iſland, &c. Though this kind of regorging gives not riſe to any extraordinary counter current, it often ſenſibly retards the progreſs of ſmall boats, and produces what is called *dead water*, which obſerves not the natural courſe of the river, but turns about in ſuch a manner as greatly obſtructs the progreſs of veſſels. Theſe dead waters are ſenſibly felt in paſſing through the arches of a bridge, eſpecially if the river be rapid. The celerity with which water runs, when the height or preſſure is the ſame, increaſes in proportion as the diameter of the canal,

through which it paſſes, is diminiſhed. The celerity of a river, therefore, in paſſing through a bridge, increaſes in the inverſe proportion of the width of the whole arches, to the total width of the river. This increaſe of celerity, in paſſing through the arch of a bridge, is ſo conſiderable, that it puſhes the water from the ſtream towards the banks, from which it is reflected, and ſometimes forms violent eddies or whirlpools. In paſſing under the bridge of St. Eſprit, the mariners are obliged ſcrupulouſly to keep the ſtream, even after leaving the bridge; for, if they allowed the boat to decline either to the right or left, it would be driven with violence againſt the banks, or, at leaſt, would be forced into the whirling or dead waters, from which they would find ſome difficulty of eſcaping. When the eddy is conſiderable, it forms a ſmall gulf with a cylindrical void in the middle, round which the water turns with rapidity. This cylindrical cavity is an effect of the centrifugal force, which makes the water endeavour to fly off from the centre of the whirlpool.

When a great ſwell of the river is about to happen, the water-men perceive a particular motion, which they call a *moving at the bottom;* that is, when the water at the bottom moves with an unuſual velocity, which, according to them, always indicates the approach of a ſudden ſwell. The motion and weight of the ſuperior waters, though not yet arrived, fail not to act upon the

waters

waters in the inferior parts of the river, and to communicate motion to them: For a river, in some respects, must be considered as a column of water contained in a tube, and its channel as a long canal, in which every motion must be communicated from one end of it to the other. Now, independent of the motion of the superior waters, their weight alone may increase the celerity of the river, and perhaps make it move quickest at the bottom; for it is well known, that, when several boats are at once pushed into a river, they increase the motion of the water below, and retard that of the superior water.

The celerity of running waters is not in exact proportion to the declivity of their channels. A river with a uniform declivity, and double to that of another, ought not, it would appear, to run with more than a double celerity: But its celerity is much more quick, being sometimes triple, sometimes quadruple, &c. The celerity depends more upon the quantity of water, and the weight of the superior waters, than upon the degree of descent. In digging the bed of a river or drain, it is unnecessary to make the descent uniform through its whole extent. A quick motion is more easily produced by making the declivity much greater at the source than at the mouth, where, like the beds of natural rivers, it is almost imperceptible, and yet they preserve their celerity, which is more or less, according to the quantity they contain; for

in great rivers, even where the ground is level, the water ſtill runs, not only with the velocity originally acquired, but with the accumulated velocity produced by the action and weight of the ſuperior waters*. To make this matter ſtill more plain, let us ſuppoſe the Seine from Pont-neuf to Pont-royal to be perfectly level, and to be ten feet deep; let us alſo ſuppoſe the bed of the river below Pont-royal and above Pont-neuf to be ſuddenly dried up; the waters, in this caſe, would run both up and down the channel, till their equilibrium was perfectly reſtored. This effect is produced ſolely by the weight of the water, which never allows it to remain at reſt till its particles are equally preſſed on all ſides, and its ſurface reduced to a perfect level. The weight of water, therefore, contributes greatly to increaſe the celerity of its motion. This is the reaſon why the greateſt celerity in a current of water is neither at the bottom nor at the ſurface, but nearly in the middle, which is preſſed both by the column above, and by the reaction from the bottom. But, what is ſtill more, when a river acquires a great celerity, it will not only preſerve it, though running through a level country, but even ſurmount heights, without

* By not attending to theſe circumſtances, M. Khun was led falſely to affirm, that the ſource of the Danube was at leaſt two German miles higher than its mouth; that the Mediterranean is 6¾ German miles lower than the ſources of the Nile; that the Atlantic ocean is half a mile lower than the Mediterranean, &c.

ſpreading

ſpreading much to a ſide, or, at leaſt, without producing an inundation of any moment.

One would be apt to imagine, that bridges, and other obſtacles erected in rivers, would create a conſiderable diminution of celerity in their whole courſe. But the difference is very ſmall. The water, upon meeting with any obſtacle, riſes, in order to ſurmount it; and the increaſe of celerity communicated by its fall, nearly compenſates the retardation occaſioned by the obſtacle. Thus, ſinuoſities, projections from the land, and iſlands, create but a ſmall variation on the total celerity of a river's courſe. The moſt conſiderable alterations are produced by the greater or leſſer quantities of water; when the quantity is ſmall, a river runs ſlow, when great, it runs with rapidity.

If rivers were always equally full, to enlarge their channels would be the beſt method of diminiſhing their rapidity, and to contain them within their banks. But, as almoſt all rivers riſe and fall, it is more neceſſary, for this latter purpoſe, to narrow their channels; for ſmall waters, with large channels, generally ſcoop out winding beds in the middle; and, when they ſwell, they follow the direction of theſe particular beds, and by ſtriking with violence againſt the banks, often do much injury to mills and other works. Theſe bad effects might be prevented, by digging gulfs in the earth at convenient diſtances. To accompliſh this purpoſe, a

part of one of the banks ſhould be cut through, and the earth removed for a conſiderable ſpace. Theſe ſmall gulfs ſhould be made in the obtuſe angles of the river; for the water, in turning, would run into them; and, of courſe, its celerity would be diminiſhed. This method might be uſeful in preventing the fall of bridges in places where ſufficient barriers cannot be erected to reſiſt the weight of the water.

The manner in which inundations are produced, merits particular attention. When a river ſwells, its celerity uniformly increaſes, till it begins to overflow the banks: From that moment its rapidity is checked, which is the reaſon why inundations always continue ſeveral days; for, though the quantity of water ſhould be diminiſhed after the commencement of the inundation, it would, notwithſtanding, continue to overflow; becauſe this circumſtance depends more on the celerity than on the quantity of water. If it were otherwiſe, rivers would often overflow their banks for an hour or two, and then retire to their channels, which never happens. An inundation, on the contrary, always laſts ſome days, although the rains have ceaſed, and leſs water runs in the river; becauſe the overflowing of waters diminiſhes their celerity; and, conſequently, although the ſame quantity of water arrives not in the ſame time as formerly, the effect is the ſame as if a larger quantity had been brought down. It may likewiſe

wiſe be here remarked, that, if a high wind blows contrary to the current of the river, the inundation will be increaſed by this occaſional cauſe, which diminiſhes the celerity of the water; but, if the wind blows in the direction of the current, the inundation will be leſs, and retire more quickly.

'The inundation of the Nile,' ſays M. Granger, 'has long been a ſubject of diſcuſſion 'among the learned. Moſt of them have conſidered it as a ſingular and wonderful phænomenon, though nothing be more natural or 'more common; for it takes place in every 'country, as well as in Egypt. The inundation 'of the Nile is occaſioned by the rains which fall 'in Ethiopia and Abyſſinia; but the north wind 'may be regarded as the principal cauſe of it: '1. Becauſe the north wind drives the clouds 'which contain this rain into Abyſſinia: 2. Becauſe it prevents the water from running out 'of the mouths of the river in any great quantity, by damming up the ſtream. The great 'effect of this wind may be remarked every 'ſeaſon; for, when it changes from north, the 'Nile loſes more water in one day than in four.'

Inundations are generally greateſt in the ſuperior parts of rivers; becauſe, as formerly obſerved, the velocity of a river uniformly increaſes till it empties itſelf in the ocean. Father Caſtelli, a ſenſible writer on this ſubject, remarks, that the banks, raiſed for the purpoſe of keeping

keeping the Po from overflowing, gradually diminish in height, as the river approaches to the sea; that, at Ferrara, which is 60 or 70 miles from the mouth of the river, the banks are about 20 feet above the ordinary level of the water; but that, at 10 or 12 miles from the sea, though the channel be equally narrow as at Ferrara, they are not above 12 feet*.

In fine, the theory of running waters is subject to many difficulties. It is not easy to give general rules which will apply to every particular case. For this purpose, experience is preferable to speculation: It is not enough that we know the common effects of rivers in general; but, if we would reason justly, and give stability to our labours, we ought to study the peculiarities of particular rivers in which we have an interest. Though the remarks I have made be generally new, a greater collection is necessary. Perhaps we shall in time acquire a distinct knowledge of this subject, and be enabled to give certain rules for directing and confining rivers in such a manner as will prevent the destruction of bridges, banks, and other damages occasioned by the impetuosity of the waters.

The greatest rivers of Europe are, the Wolga, the course of which, from Reschow to Astracan on the Caspian Sea, is about 650 leagues; the Danube, which runs about 450 leagues,

* See Racolta d'autori che trattano del moto dell'acque, vol. i. p. 125.

from

from the mountains of Switzerland to the Black Sea; the Don, the course of which, from the source of the Sosna, which receives it, to the Black Sea, is 400 leagues; the Nieper, which likewise falls into the Black Sea, after running 350 leagues; the Duine, which empties itself in the White Sea, runs a course of about 300 leagues, &c.

The greatest rivers of Asia are the Hoanho, in China, which rises at Raja-Ribron, and after running 850 leagues, falls into the middle of the gulf of Changi, in the Chinese sea; the Jenisca, which runs from Lake Selinga to the northern sea of Tartary, a course of about 800 leagues; the Oby, the course of which, from Lake Kila to the north sea beyond Waigat's Straits, is about 600 leagues; the river Amour, in east Tartary, has a course of 575 leagues, from the head of the river Kerlon, which falls into it, to the sea of Kamtschatka; the river Menancon may be measured from the source of the Longmu, which falls into it, to its mouth at Poulo-condor; the Kian, the course of which is about 550 leagues, from the source of the Kinxa, which it receives, to its termination in the sea of China; the Ganges, which has a course nearly of the same extent with the Kian; the Euphrates, computing from the source of the Irma, which it receives, runs about 500 leagues; the Indus, which runs about 400 leagues, and falls into the Arabian sea on the east of Guzarat;

rat; and the Sirderoias, which runs about 400 leagues, and falls into Lake Aral.

The greateſt rivers of Africa are, the Senegal, the courſe of which, comprehending the Niger, which is a continuation of it, and the ſource of the Gombarou, which falls into the Niger, is about 1125 leagues; the Nile, which riſes in Upper Ethiopia, runs about 970 leagues. There are others, the courſes of which are but partially known, as the Zaira, the Coanza, the Couama, and the Quilmanci, each of which we are acquainted with to the extent of 400 leagues.

Laſtly, in America, the river of the Amazons runs more than 1200 leagues, if we reckon from the lake near Guanuco, 30 leagues from Lima, where the Maragnon riſes; or, even computing from the ſource of the river Napo, near Quito, the courſe of the Amazons is more than 1000 leagues*.

The courſe of the river St. Lawrence in Canada is more than 900 leagues, computing from its mouth to Lake Ontario, from that to Lake Huron, Lake Superior, Lake Alemipigo, Lake Chriſtinaux, and the lake of the Aſſiniboils, the waters of all which fall into one another, and at laſt into the river St. Lawrence.

The river Miſſiſippi runs more than 700 leagues, from its mouth to any of its ſources, which are not far from the lake of the Aſſiniboils.

* See Voyage de Condamine, p. 15.

The river Plata extends more than 800 leagues, from its mouth to the ſource of the Parana, which it receives.

The river Oronoko runs more than 575 leagues, reckoning from the ſource of the river Caketa, near Paſto, which partly falls into the Oronoko, and partly runs towards the river of the Amazons*.

The Madera, which falls into the Amazons, extends more than 660 leagues.

In order to compute the quantity of water diſcharged into the ſea by all the rivers, we ſhall ſuppoſe, which is nearly the truth, that one half of the earth's ſurface is ſea, and the other half dry land: We ſhall likewiſe ſuppoſe the mean depth of the ſea to be about 230 fathoms. The total ſurface of the earth is 170981012 ſquare miles, and that of the ſea is 85490506 ſquare miles, which being multiplied by 1-fourth, the depth of the ſea, gives 21372626 cubic miles for the quantity of water contained in the whole ocean. Now, to compute the quantity diſcharged into the ocean by the rivers, let us take a river, the velocity and quantity of whoſe waters are known; the Po, for example, which paſſes through Lombardy, and waters a country of 380 miles in length. According to Riccioli, the breadth of the Po, before it divides into branches, is 100 perches of Boulogne, or 1000 feet; and its depth is 10 feet; and it runs at the rate of 4 miles in an

* See M. Condamine's Map.

hour:

hour: Consequently the Po discharges into the sea 200,000 cubical perches of water in an hour, or 4,800,000 in a day. But a cubic mile contains 125,000,000 cubic perches; of course, it will require 26 days to discharge into the sea a cubic mile of water. It only remains to determine the proportion that the Po bears to all the rivers of the earth taken together, which cannot be done exactly. But, to approach nearly to the truth, let us suppose that the quantity of water which the sea receives from the great rivers in every country, is proportioned to the extent of the surfaces of these countries; and, consequently, that the country watered by the Po, and by the rivers which fall into it, is to the total surface of the dry land as the Po is to all the rivers of the earth. Now, by the most exact charts, it appears that the Po, from its origin to its mouth, traverses a country of 380 miles in length; and the rivers which fall into it on each side arise from sources which are about 60 miles distant from the Po. Thus, the Po, and the rivers it receives, water a country 380 miles long, and 120 broad, which makes 45600 square miles. But the surface of the dry land is 85490506 square miles; consequently, the quantity of water carried to the sea by all the rivers will be 1874 times greater than the quantity discharged by the Po. But, as 26 rivers, equal to the Po, furnish a cubic mile of water each day, it follows, that, in the space of a year,

1874 rivers equal to the Po, will carry to the ſea 26308 cubic miles of water; and that in 812 years, all theſe rivers would diſcharge 21372626 cubic miles, which is a quantity equal to what is contained in the ocean; of courſe, if the ocean were empty, 812 years would be neceſſary to fill it by the rivers*.

It is a reſult of this calculation, that the quantity of water raiſed from the ſea by evaporation, and tranſported upon land by the winds, is from 20 to 21 inches in the year, or about $\frac{2}{3}$ of a French line each day. This evaporation, though tripled to make allowance for what falls back into the ſea from the clouds, is very inconſiderable. Mr. Halley † has clearly demonſtrated, that the vapours tranſported from the ſea, and diſcharged upon the land, are ſufficient to maintain all the rivers and lakes in the world.

After the Nile, the Jordan is the largeſt river in the Levant, or even in Barbary. It diſcharges each day into the Dead Sea about 6,000,000 of tons. All this water, and more, is carried off by evaporation; for, according to Halley's calculation of 6914 tons evaporated from each ſuperficial mile, the Dead Sea, which is 72 miles long, and 18 broad, muſt loſe every day, by evaporation, near 9,000,000 of tons; that is, not only all the water it receives from the Jordan, but from the ſmaller rivers which come from

* See Keil's Examination of Burnet's Theory, p. 126.

† See Phil. Tranſ. num. 192.

from the mountains of Moab, and elsewhere. Of course, this sea has no occasion to communicate with any other by subterraneous passages*.

The most rapid of all rivers are, the Tigris, the Indus, the Danube, the Yrtis in Siberia, the Malmistra in Cilicia, &c †. But, as was formerly remarked, the velocity of rivers depends both on the declivity and the weight of water. In examining the globe, we find that the Danube has less declivity than the Po, the Rhine, or the Rhone; for the course of the Danube is longer, and it falls into the Black Sea, which is higher than the Mediterranean, and perhaps than the ocean.

Great rivers, in their course, are constantly receiving small ones into their channels. The Danube, for example, receives more than 200 brooks and rivulets. But if we reckon only rivers of some consideration, we will find, that the Danube receives 30 or 31, the Wolga 32 or 33, the Don 5 or 6, the Nieper 19 or 20, the Duine 11 or 12. The Hoanho, in Asia, receives 34 or 35 rivers, the Jenisca more than 60, the Oby an equal number, the Amour about 40, the Kian, or river Nankin, 30, the Ganges more than 20, the Euphrates 10 or 11, &c. In Africa, the Senegal receives more than 20 rivers; the Nile receives none lower than 500 leagues from its mouth, the last which falls into it being the Moraba; and from this place to its

* See Shaw's Travels.

† See Varenii Geog. p. 178.

source

ſource, it receives about 12 or 13. In America, the Amazons receives more than 60 conſiderable rivers, St. Lawrence about 40, reckoning thoſe which fall into the lakes, the Miſſiſippi more than 40, the Plata above 50, &c.

Upon the ſurface of the earth, there are elevated countries which ſeem to be points of partition marked out by nature for the diſtribution of the waters. In Europe, one of theſe points is Mont Saint-Godard, and its environs. Another point is the country ſituated between the provinces of Belozera and Wologda in Muſcovy, from which many rivers deſcend, ſome into the White Sea, ſome into the Black, and others into the Caſpian. In Aſia, there are ſeveral points of partition, as the country of the Mogul Tartars, ſome of whoſe rivers run into the ſea of Nova Zembla, others into the gulf of Linchidolin, others into the ſea of Corea, and others into that of China; and the Leſſer Thibet, the rivers of which run into the Chineſe ſea, into the gulf of Bengal, the gulf of Cambaia, and the Lake Aral. The province of Quito, in America, diſcharges its rivers into the ſouth and north ſeas, and into the gulf of Mexico.

In the Old Continent, there are about 430 rivers which directly fall either into the Ocean, or into the Mediterranean and Black Seas. But, in the New Continent, we know of only 135 rivers which fall immediately into the ſea. In

this number I have reckoned none which are not as large as the river Somme in Picardy.

All theſe rivers tranſport, from the countries through which they paſs, into the ſea, great quantities of mineral and ſaline particles. The particles of ſalt, which diſſolve in water, are eaſily carried down to the ſea. Several philoſophers, and particularly Halley, have alledged, that the ſaltneſs of the ſea proceeds alone from the particles of ſalt tranſported by the rivers: Others maintain, that this ſaltneſs was coeval with the ſea itſelf, and that the ſalt was created to prevent the waters from corrupting. But the agitation of the ſea by the winds and the tides is, I imagine, a cauſe equally powerful as the ſalt in preſerving it againſt putrifaction; for, when barrelled up, it corrupts in a few days. And Boyle informs us of a navigator who was overtaken with a calm which laſted 13 days, and who aſſured him, that the water became ſo putrid, that, if the calm had continued much longer, the whole crew would have periſhed*. Sea-water is alſo impregnated with a bituminous oil, which renders it both unwholeſome and diſagreeable to the taſte. The quantity of ſalt in ſea-water is about a fortieth part, and it is nearly of an equal ſaltneſs at the ſurface and at the bottom, under the Line and at the Cape of Good Hope; though there are ſome particular places, as off the Moſambique coaſt, where it is more ſalt than

* See Boyle, vol. iii. p. 222.

in others*. It is likewife faid to be lefs falt within the Arctic circle: But this phænomenon may proceed from the immenfe quantities of fnow, and the large rivers which fall into thefe feas, and from the proportional defect of evaporation.

However this matter ftands, I believe, that the faltnefs of the ocean is not only occafioned by the many banks of falt at the bottom of the fea, and along the coafts, but likewife by the falts continually brought down by the rivers; that Halley was right in his conjecture that there was originally little or no falt in the fea, but that its faltnefs gradually augmented in proportion as falt was fupplied by the rivers; that the degree of faltnefs is perpetually increafing; and, confequently, that, by computing the total quantity of falt carried down by the rivers, we might be enabled to difcover the real age of the world. Mr. Boyle affirms, on the authority of divers and pearl-fifhers, that the water is colder in proportion to its depth; and that, at great depths, the cold becomes fo exceffive as to oblige them to come up much fooner than ufual. But the weight of the water may be as much the caufe of their uneafinefs as the intenfenefs of the cold, efpecially when they defcend 300 or 400 fathom. Divers, however, feldom go deeper than 100 feet. The fame author relates, that, in a voyage to the Eaft Indies, when they ar-

* See Boyle, vol. iii. p. 217.

rived at the 35th degree of south latitude, they sounded to the depth of 400 fathoms, and when the lead, which weighed about 30 pounds, was drawn up, it had become as cold as ice. It is likewise a common practice at sea to sink the bottles several fathoms, in order to cool their wine; and it is said, that the deeper the bottles are sunk, the wine becomes the cooler.

These facts would lead us to imagine, that the sea-water was salter at the bottom than at the surface. But they are opposed by facts of a contrary nature: Experiments have been made with vessels which opened only at a certain depth, and the water was not found to be salter than that at the surface: There are even examples of the water at the bottom being fresher than at the surface: This phænomenon is exhibited in all those places where springs arise from the bottom of the sea, as near Goa, at Ormus, and in the sea of Naples, in which there are many warm springs.

In other places, sulphureous springs and beds of bitumen have been discovered at the bottom of the sea; and, upon land, there are numerous springs of bitumen which run into the sea. At Barbadoes, there is a fountain of bitumen which runs from the rocks into the sea. Bitumen and salt, then, are the principal ingredients in sea-water. But it is blended with many other substances; for its taste differs considerably in different parts of the ocean: Besides, agitation and the

the heat of the ſun change the natural taſte of ſea-water; and the different colours of different ſeas, and even of the ſame ſea at different times, prove it to be mixed with many heterogeneous bodies, which are detached either from the bottom, or carried down by the rivers.

Moſt countries that are furniſhed with large rivers are ſubject to periodical inundations; and thoſe rivers which have long courſes overflow with the greateſt regularity. Every body has heard of the inundations of the Nile, the waters of which, though ſpread over a large track of country, and at a great diſtance from the ſea, preſerve their ſweetneſs and tranſparency. Strabo and other ancient authors tell us, that the Nile had ſeven mouths; but now only two which are navigable remain: A third canal, indeed, ſupplies the ciſterns of Alexandria; and there is a fourth, which is ſtill leſs conſiderable. As the cleaning of theſe canals has long been neglected, they are moſtly in ruins. In theſe works the ancients employed annually a vaſt number of workmen and ſoldiers, who carried off the mud and ſand which this river brings down in great quantities. The overflowing of the Nile is occaſioned by the rains which fall in Ethiopia: They begin in April, and end not till September. During the firſt three months, the days are ſerene and beautiful; but the ſun no ſooner ſets, than the rains begin, continue inceſſantly till ſunriſing, and are commonly accompanied with

thunder and lightning. The inundation in Egypt begins about the 17th of June; it generally takes 40 days in ſwelling, and as many in ſubſiding. The whole flat country of Egypt is overflowed: But the inundation is not now ſo great as in ancient times; for Herodotus affirms, that the Nile ſwelled 100 days, and required an equal time to ſubſide. If this fact be true, the difference can be aſcribed to no other cauſes but the gradual elevation of the land by the mud brought down and depoſited, and the diminution in the height of the mountains from which this river derives its ſource. It is natural to think, that the height of the mountains is diminiſhed; for the heavy rains that fall in theſe regions during one half of the year, bring down great quantities of ſand and earth from the tops of the mountains into the valleys, from which they are tranſported by torrents into the channel of the Nile, and are partly depoſited on the land by the inundations.

The Nile is not the only river that has regular and annual overflowings: The Pegu, which is equally regular in its inundations, has, from this circumſtance, got the name of the *Indian Nile.* It overflows the country for 30 leagues beyond its banks, and, like the Nile, leaves great quantities of mud and ſlime, which enrich the ground ſo much, that it produces excellent paſture for cattle, and enables the inhabitants to export

export rice*. The Niger, or, which is the ſame thing, the upper part of the Senegal, overflows and covers the whole flat country of Nigritia. Its inundations, like thoſe of the Nile, begin about the middle of June, and increaſe for 40 days. The Plata, in Braſil, overflows annually, and at the ſame time with the Nile. The Ganges, the Indus, the Euphrates, and ſome other rivers, produce annual inundations. But all rivers are not ſubject to periodic inundations: Theſe proceed from a combination of cauſes, which, at the ſame time, augment the quantity of water, and diminiſh its velocity.

We formerly remarked, that the declivity of rivers gradually diminiſh till they arrive at the ſea. But, in ſome places, the declivity is more ſudden, and forms what is called *a cataract*, which is nothing more than an unuſually rapid fall of the water. In the Rhine, for example, there are two cataracts, one at Bilefeld, and the other near Schafhouſe. The Nile has ſeveral cataracts: Two of the moſt remarkable fall from a great height between two mountains. In the Wologda, in Muſcovy, there are alſo two, near Ladoga. The Zaire, a river in Congo, commences with a large cataract, which falls from the top of a mountain. But the moſt celebrated cataract is that of the river Niagara in Canada: It falls, in a prodigious torrent, 156 feet of perpendicular height, and is a fourth part of

* See Les Voyages d'Ovington, tom. ii. p. 290.

a league in breadth. The vapour of the water riſes to the clouds, is ſeen at the diſtance of five leagues, and, when the ſun ſhines above it, exhibits a beautiful rainbow. Below this cataract, the whirlpools and commotions of the waters are ſo tremendous, as to render navigation impracticable for ſix miles: and immediately above the cataract, the river is much narrower than higher up *. Charlevoix † deſcribes it in the following manner:

'My firſt care, after my arrival, was to viſit 'the nobleſt caſcade, perhaps, in the world; but 'I preſently found the Baron de la Hontan had 'committed ſuch a miſtake with reſpect to its 'height and figure, as to create a ſuſpicion that 'he had never ſeen it. If, however, you meaſure its height by that of the three mountains 'you are obliged to climb to get at it, it does 'not fall much ſhort of what the map of M. 'Deſliſle makes it, that is, 600 feet. He has 'probably adopted this paradox, either on the 'faith of the Baron de la Hontan, or of Father 'Hennepin. But, after I arrived at the ſummit 'of the third mountain, I obſerved, that, in the 'ſpace of three leagues, which I had to walk 'before I came to this piece of water, though 'you are ſometimes obliged to aſcend, you muſt 'yet deſcend ſtill more; a circumſtance to which 'travellers ſeem not to have ſufficiently attended. As it is impoſſible to approach it but on 'one

* See Phil. Tranſ. Abridg. vol. vi. part ii. p. 119.

† Tom. iii. p. 353.

'one ſide, and conſequently to ſee it, except in 'profile, it is no eaſy matter to meaſure its 'height with inſtruments. It has, however, 'been attempted by means of a pole tied to a 'long line, and, after many trials, it has been 'found to be only 115, or 120 feet high. But 'it is impoſſible to be ſure that the pole has not 'been ſtopt by ſome projecting rock; for, 'though it was always drawn up wet, as well 'as the end of the line to which it was tied, 'this circumſtance proves nothing, as the water 'which precipitates itſelf from the mountain, 'riſes very high in foam. For my own part, 'after having examined it on all ſides, where it 'could be viewed to the greateſt advantage, I 'am inclined to think that we cannot allow it 'to be leſs than a hundred and forty or fifty 'feet high.

'As to its figure, it reſembles that of a horſe-'ſhoe, and is about 400 paces in circumference. 'It is divided into two, exactly in the middle, 'by a very narrow iſland, half a quarter of a 'league long. It is true, theſe two parts very 'ſoon unite; that on my ſide, and which I 'could have a ſide view of only, has ſeveral 'branches which project from the body of the 'caſcade, but that which I viewed in front, ap-'peared to me quite entire. The Baron de la 'Hontan mentions a torrent, coming from the 'weſt, which, if this author has not invented it, 'muſt certainly fall through ſome channel dur-'ing the melting of the ſnows only.'

Three

Three leagues from Albany, in the province of New York, there is a cataract of 50 feet perpendicular height, the vapour of which likewise gives rise to a rainbow*.

In every country where the number of men is too inconsiderable for forming and supporting polished societies, the surface of the earth is more unequal and rugged, and the channels of rivers are more extended, irregular, and often interrupted by cataracts. The Rhone and the Loire would require the operation of several ages before they became navigable. It is by confining and directing the waters, and clearing the bottoms of rivers, that they acquire a fixed and determinate course. In thinly inhabited regions, nature is always rude, and sometimes deformed.

Some rivers lose themselves in the sands, and others seem to precipitate into the bowels of the earth. The Guadalquiver in Spain, the river of Gottenburg in Sweden, and even the Rhine, disappear under ground. It is affirmed, that, in the west part of the Island of St. Domingo, there is a pretty high mountain, at the foot of which are several large caverns that receive the rivers and brooks; and the noise of their fall is heard at the distance of seven or eight leagues†. The number of rivers, however, which disappear in the earth, is very small; and they seem not to

* See Phil. Transf. Abridg. vol. vi. part ii. p. 119.
† See Varen. Geogr. p. 43.

descend very deep. It is more probable, that, like the Rhine, they lose themselves by dividing and dispersing through a large surface of sand, which is very common with those small rivers that run through dry and sandy ground, of which there are many examples in Africa, Persia, Arabia, &c.

The rivers of the north carry down to the sea prodigious quantities of ice, which, by accumulating, form those enormous masses, so dangerous to the mariner. The straits of Waigat, which is frozen during the greatest part of the year, is most remarkable for these masses of ice, that are constantly brought into the straits by the river Oby. They attach themselves all along the coasts, and rise to great heights. The middle of the strait freezes last, and the ice, of course, does not rise so high as on each side. When the north wind ceases, and it blows in the direction of the straits, the ice begins to melt and to break in the middle; then large masses are detached and transported into the open sea. The wind, which blows during the whole winter from the north, over the frozen country of Nova Zembla, renders the regions watered by the Oby, and all Siberia, so cold, that, at Tobolski, in the 57th degree, there are no fruit trees, though at Stockholm in Sweden, and even in higher latitudes, they have fruit trees and leguminous plants. This difference proceeds not, as has been imagined, from the sea of Lapland being

being colder than that of the ſtraits, nor from the country of Nova Zembla being colder than that of Lapland, but from this circumſtance alone, that the Baltic and the ſea of Bothnia ſoften the rigour of the north wind; whereas, in Siberia, there is nothing to check its activity. This ſolution is a reſult of experience. The cold is never ſo intenſe near the ſea-coaſts as in the interior parts of a country. There are plants which endure the open air all winter at London, which cannot be preſerved at Paris: and Siberia, which is a vaſt continent, is, for this reaſon, colder than Sweden, which is almoſt ſurrounded with the ſea.

Spitzbergen is the coldeſt country in the world: It runs as far as the 78th degree of north latitude, and is compoſed of ſmall, pointed mountains. Theſe mountains conſiſt of gravel, and of flat ſtones, like gray ſlate, heaped upon one another. According to the accounts of voyagers, theſe hills are raiſed by the winds, and new ones appear every ſeaſon. In this country no quadrupeds live but the rein deer, which feeds upon moſs. Beyond theſe hills, and above a league from the ſea, the maſt of a ſhip was lately found with a pully fixed to one end of it; from which circumſtances, it has been concluded, that this is a new country, and that it was formerly covered with the ſea: It is uninhabited and uninhabitable; for the hills have no conſiſtence, but are looſe and moveable; and

a va-

a vapour proceeds from the earth, ſo cold and penetrating, as to preclude the poſſibility of remaining any time upon this dreary and inhoſpitable land.

The whale-fiſhing veſſels arrive at Spitzbergen in July, and depart from it about the middle of Auguſt. The ice permits them not to arrive ſooner, or to remain longer. In theſe ſeas there are prodigious boards of ice, clear and ſhining as glaſs, and from 60 to 80 fathoms thick; and, in ſome places the ſea appears to be frozen to the bottom*.

The ſeas of North America are likewiſe much infeſted with ice, as in Aſcenſion-bay, in Hudſon's, Cumberland's, Davis's, and Frobiſher's ſtraits, &c. We are aſſured by Robert Lade, that the mountains of Frieſland are entirely covered with ſnow; and that the ice ſurrounds the coaſts, and, like a bulwark, prevents all approach to them. 'It is remarkable,' ſays he, 'that, in 'this ſea, we meet with iſlands of ice, more than 'half a league in circumference, exceedingly 'high, and deſcend from 70 to 80 fathoms 'deep. This ice, which is ſweet, is perhaps 'originally formed in the rivers or ſtraits of the 'adjacent lands, &c. Theſe iſlands or mountains of ice are moveable, and, in ſtorms, they 'follow the tract of a ſhip, as if they were 'drawn after her by a rope. Some of them

* See recueil des voyages du Nord, tom. i. p. 154.

'riſe

'rise so high above water, that they surmount 'the tops of the tallests masts*,' &c.

In the voyages collected for the use of the Dutch East India Company, we have the following account of the ice off Nova Zembla; 'At Cape Troost, the weather was so foggy, as 'to oblige us to moor our vessel to a bank of 'ice, which was 36 fathoms below, and 16 'above the surface of the water. On the 10th 'of August, the ice began to separate, and to 'float; we then remarked, that the mass to 'which our vessel had been moored, touched 'the bottom; for, though the others were all 'in motion, and struck against it, and against 'each other, it remained immoveable. We 'were now afraid of being frozen in, or dashed 'to pieces; we, therefore, endeavoured to escape 'from this latitude, though the vessel, in 'her course, was obliged to push through the 'ice, which made a great noise round us for 'a considerable distance: we at last anchored 'along another board of ice, where we remain- 'ed that night.

'During the first watch, the ice began to 'split, with an inconceivable noise. The ship's 'head kept so strongly to the current in which 'the ice-boards floated, that we were obliged to 'veer the cable in order to get her off. We 'counted above 400 blocks of ice, which sank

* See Lade's voyages.

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'10 fathoms below the water, and appeared to 'rise about two fathoms above it.

'We then moored the vessel to another block 'of ice, which was immersed below the surface 'about six fathoms. At a little distance from 'this station we perceived a large bank, which 'was pointed like a cone, and reached to the 'bottom of the sea: we approached it, and 'found it to be 20 fathoms below, and about '12 above the surface of the water.

'On the 11th, we sailed up to another bank, 'which was 18 fathoms below the surface, and '10 fathoms above it.

'The Dutch, on the 21st, advanced a great 'way between the boards of ice, and anchored 'during the night. Next morning they retired, 'and moored to a bank which was 18 fathoms 'below, and 10 above the water. They climbed 'to the top, and remarked, as a singular phæ-'nomenon, that it was covered with earth, and 'that they found there about 40 eggs. Its co-'lour was a fine azure blue, and totally differ-'ent from that of the other masses. This cir-'cumstance gave rise to various speculations; 'some imagining it to be an effect of the ice, 'and others thought the whole was a mass of 'frozen earth*.'

Wafer met with many floating pieces of ice, off Terra del Fuego, which were so large that

* See Troisieme voyage des Hollandois par le Nord, tom. i. p. 46.

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he at firſt imagined them to be iſlands: ſome of them, he remarks, appeared to be a league or two in length, and the largeſt of them ſeemed to riſe 400 or 500 feet above the ſurface of the water.

All theſe boards of ice, as I have remarked in the 6th Article, are tranſported from the rivers into the ſea. Thoſe in the ſea of Nova Zembla and in the Straits of Waigat, come from the Oby, and, perhaps, from the Jeniſca, and other great rivers in Siberia and Tartary; thoſe of the Hudſon's Straits, from Aſcenſion-bay, into which many rivers in North America empty themſelves; and thoſe of Terra del Fuego, from the ſouthern continent. If fewer of them appear in the northern coaſts of Lapland than in thoſe of Siberia and Waigat's Straits, it is becauſe all the Lapland rivers fall into the gulf of Bothnia, and none of them into the north ſea. They may likewiſe be formed in ſtraits, where the tides riſe higher than in the open ſea; and, conſequently, where the boards of ice which float on the ſurface may accumulate and produce maſſes or banks of ſeveral fathoms high. But, with regard to thoſe which riſe to the height of four or five hundred feet, it appears, that they can no where be produced but near very elevated coaſts; and I imagine, that, when the ſnows which cover theſe coaſts melt, the water runs down upon the boards of ice, and, by freezing anew, gradually augments their

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ſize, till they arrive at this amazing height; that, in a warm ſummer, the action of the winds, the agitation of the ſea, and perhaps their own weight, may detach them from the coaſts, and ſet them adrift; and that they may even be tranſported into temperate climates before they are entirely diſſolved.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XI.

Of Seas and Lakes.

THE dry land is every where ſurrounded by the ocean; it penetrates, ſometimes by large openings, and ſometimes by ſmall ſtraits, into the interior parts of different countries, and forms mediterranean ſeas, ſome of which are affected by the motion of the tides, and others not. We ſhall, in this article, trace the ocean through all its windings; and, at the ſame time, give an enumeration of the mediterranean ſeas, which we ſhall endeavour to diſtinguiſh from what are called bays or gulfs, and lakes.

The ſea that waſhes the weſtern coaſts of France, forms a gulf between Spain and Brittany. This gulf is, by navigators, called the Bay of

of Biſcay: It is very open, and advances fartheſt into the land between Bayonne and St. Sebaſtian. It likewiſe advances conſiderably at Rochelle and Rochefort. This bay begins at Cape Ortegal, and terminates at Breſt, where a ſtrait commences between the ſouth point of Brittany and the Lizard Point. This ſtrait, which is at firſt pretty wide, forms a ſmall bay on the coaſt of Normandy, the moſt advanced point of which is at Auranche. It continues pretty large till it arrives at the channel of Calais, where it is very narrow; it then ſuddenly enlarges, and terminates between the Texel and the coaſt of Norwich: At the Texel, it forms a ſmall ſhallow mediterranean called *Zuiderſee*, and ſeveral large gaps or advances, the waters of which are not of a conſiderable depth.

After this, the ocean forms a large bay called the *German Sea*, which commences at the northmoſt point of Scotland, and runs along the eaſt coaſt of Britain the length of Norwich; and from thence to the Texel, along the coaſts of Holland and Germany, of Jutland and Norway, as far as Bergen. This bay may even be conſidered as a mediterranean; for the Orkney iſlands nearly ſhut up its mouth, and ſeem, by their direction, to be a continuation of the mountains of Norway. It forms a large ſtrait, which commences at the ſouth point of Norway, and continues pretty broad to the iſland of Zetland, where it ſuddenly contracts, and forms, between

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the coasts of Sweden and the islands of Denmark and Jutland, four small straits; after which, it widens to a small bay, the most advanced point of which is at Lubec; from thence, to the south extremity of Sweden, it continues pretty broad; then it enlarges more and more, and forms the Baltic, which is a mediterranean sea, extending, from south to north, near 300 leagues, if the gulf of Bothnia, which is a continuation of it, be comprehended. In the Baltic are two bays, that of Livonia, the most advanced point of which is near Mittau and Riga, and that of Finland, which is a branch of the Baltic, extending between Livonia and Finland to Petersburgh, and communicating with Lake Ladoga, and even with Lake Onega, which joins the White Sea by means of the river Onega. The whole body of water which forms the Baltic, the gulfs of Bothnia, of Finland, and of Livonia, ought to be regarded as an immense lake, supported by a great number of rivers, as the Oder, the Vistula, the Niemen, the Droine in Germany and Poland; by other rivers in Livonia and Finland, by others still more considerable which come from Lapland, as the Tornea, the Calis, the Lula, the Pithea, the Uma; and by several from Sweden. These rivers, which, in general, are large, amount to more than 40, including those which fall into them, and cannot fail to convey a quantity of water sufficient to supply the Baltic. Besides, there are no tides in the Baltic, and its

water

water has very little ſaltneſs: And if the ſituation of the land, and the number of lakes and marſhes in Finland and Sweden, which are contiguous to the Baltic, be taken into conſideration, we ſhall be inclined to regard it not as a ſea, but as a great lake formed by the waters which it receives from the adjacent countries, and which have forced for themſelves a paſſage near Denmark into the ocean, into which, according to the relation of voyagers, it ſtill continues to run.

From the commencement of the bay which goes by the name of the German Sea, and which terminates beyond Bergen, the ocean follows the coaſts of Norway, Swediſh Lapland, North Lapland, and Muſcovite Lapland, at the eaſtern part of which it forms a large ſtrait, and gives riſe to the mediterranean called the White Sea, which may alſo be conſidered as a great lake; for it receives twelve or thirteen large rivers, which are more than ſufficient to ſupply it with water; and its water contains but little ſalt. Beſides, it very nearly, in ſeveral places, communicates with the Baltic; and it has an evident communication with the gulf of Finland; for, in aſcending the river Onega, we arrive at a lake of the ſame name, which is joined by two rivers to Lake Ladoga; and this laſt communicates by a large branch with the gulf of Finland; and there are, in Swediſh Lapland, ſeveral places from which the waters run almoſt indifferently either into the White Sea or into the gulfs of

Bothnia and of Finland. This whole country is full of lakes and marſhes, and, therefore, it ſeems probable, that the Baltic and White Seas were the receptacles of its waters, and that, in time, they diſcharged themſelves into the German and Frozen Seas.

On leaving the White Sea, and coaſting the iſland of Candenos, and the north of Ruſſia, the ocean advances a ſmall arm into the land at the mouth of the river Petzora. This arm, which is about 40 leagues in length, by 8 or 10 in breadth, may rather be regarded as a collection of water formed by the river, than as a gulf of the ſea; for it alſo contains very little ſalt. In this place the land runs out in a promontory terminated by the ſmall iſlands of Maurice and of Orange; and between this promontory and the neighbouring land to the ſouth of Waigat's ſtrait, there is a bay of about 30 leagues long, which belongs to the ocean, and is not formed by rivers. This is ſucceeded by Waigat's ſtrait, which lies nearly under the 70th degree of north latitude; it is not above 8 or 10 leagues in length, and it communicates with the ſea which waſhes the north coaſts of Siberia. As this ſtrait is blocked up with ice during the greateſt part of the year, it is very difficult to penetrate into the ſea beyond it. This paſſage has been tried in vain by many navigators; and thoſe who ſucceeded have not given us exact charts of the ſea, which they call the Pacific Sea.

Sea. By the moſt recent charts, and by the beſt globes, it appears, that this ſea may be only a mediterranean, having no connection with the great ſea of Tartary; for it ſeems to be ſhut up and bounded to the ſouth by the country of the Samoides, which is now well known, and which extends from the Straits of Waigat to the mouth of the river Jeniſca: To the eaſt, it is bounded by Jelmorland; to the weſt by Nova Zembla; and, though we know not the extent of this ſea to the north and north-eaſt, as the land ſeems not to be interrupted, it is probable that the Pacific Sea is only a mediterranean; and that it is bounded by land, and has no communication on that ſide with the ocean. What eſtabliſhes this fact is, that, in departing from the Straits of Waigat, the whole weſt and north coaſts of Nova Zembla, the length of Cape Deſire, have been traverſed; that, from this Cape, the coaſts of Nova Zembla have been traced to a ſmall bay about the 75th degree, where ſome Dutchmen paſſed a dreadful winter in 1596; and that, beyond this gulf, the land of Jelmorland was diſcovered in 1664, which is ſeparated from Nova Zembla only by a few leagues of land; ſo that the only land unknown is a ſmall ſpot near this little bay juſt now deſcribed; and this ſpot exceeds not, perhaps, 30 leagues in length. If, therefore, the Pacific Sea joins with the eaſtern ocean, it muſt be by means of this ſmall bay, which is the only way by which this mediter-

ranean can have any communication with the eaftern ocean. And, even on the fuppofition that fuch a communication exifted, as this bay lies in the 75th degree of latitude, it would be neceffary, to gain this open fea, to keep five degrees farther north. It is apparent, therefore, that, in attempting a north paffage to China, it is better to fail beyond Nova Zembla to the 77th or 78th degree, where the fea is more open and clearer of ice, than to perfift in paffing the frozen ftraits of Waigat, when it is even uncertain whether the fea beyond them has any communication with the eaftern ocean.

The coaft has been traced from Nova Zembla and Jelmorland to the mouth of the Chotanga, which is about the 73d degree; beyond which an unknown coaft extends about 200 leagues. We only know, from the Ruffians who travelled by land into thefe climates, that the country is not interrupted; and, in their charts, the rivers are delineated, and they called the inhabitants *Populi Palati*. This interval of unknown coaft extends from the mouth of the Chotanga to that of Kauvoina, in the 66th degree of latitude. The bay of Linchidolin, in which the Ruffians fifh whales, advances fartheft into the land at the mouth of the Len, which is a confiderable river. This bay is very open, and pertains to the fea of Tartary.

From the mouth of the Len, the northern coaft of Tartary runs about 500 leagues eaft-

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ward to a peninſula inhabited by a people called Schelates. It is the moſt northern point of Tartary, and lies under the 72d degree of latitude. In this extent of 500 leagues, the ocean forms neither bays nor arms; only from the peninſula of the Schelates, to the mouth of Korvinea, there is a conſiderable elbow or projection. This point is the eaſtern extremity of the north coaſt of the Old Continent, and Cape North in Lapland is the weſtern extremity. Thus, we have of northern coaſt from Cape North in Lapland, to the extremity of the country of the Schelates, an extent of 1700 leagues, including the ſinuoſities of bays; and it meaſures about 1100 leagues in a ſtraight line.

Let us next take a ſurvey of the eaſtern coaſts of the Ancient Continent. We ſhall begin at the extreme point of the country of the Schelates, and deſcend towards the equator. The ocean firſt makes a turn between the country of the Schelates and that of the Tſchutſchi, which laſt projects conſiderably into the ſea. To the ſouth of this country, there is a ſmall open bay, called the bay of Suctoikret. This bay is ſucceeded by another, which advances, like an arm, about 40 or 50 leagues into the land of Kamtſchatka: after which the ocean flows in, by a narrow ſtrait, full of ſmall iſlands, between the ſouthern point of Kamtſchatka and the northern point of the land of Jeſſo, and forms a large mediterranean, which we ſhall now deſcribe in detail.

tail. It confifts of the fea of Kamtfchatka, in which there is a confiderable ifland, called the ifland of *Amour*. An arm of this fea runs north-eaft. But, both this arm and the fea of Kamtfchatka may, at leaft in part, be formed by the rivers which flow into it from the lands of Kamtfchatka, and thofe of Tartary. However this matter ftands, the fea of Kamtfchatka communicates, by a very long ftrait, with the fea of Corea, which is another part of this mediterranean; and the whole together, extending more than 600 leagues in length, is bounded, on the weft and north, by the lands of Corea and Tartary; and, on the eaft and fouth, by thofe of Kamtfchatka, Jeffo, and Japan, without having any other communication with the ocean than by the ftrait between Kamtfchatka and Jeffo; for it is uncertain whether the communication between Japan and the land of Jeffo, though laid down in fome charts, has a real exiftence; and, even fuppofing it did exift, the fea of Kamtfchatka and that of Corea would ftill be regarded as forming together a great mediterranean, feparated on all fides from the ocean, and not as a bay; for it communicates not with the ocean by its fouthern ftrait, but with the Chinefe Sea, which is rather a mediterranean than a bay.

In the preceding article, it was remarked, that the fea had a conftant motion from eaft to weft; and that, confequently, the great Pacific Ocean

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is making continual efforts againſt the eaſtern coaſts. An accurate examination of the globe will confirm the concluſions we have drawn from this obſervation; for it appears, that from Kamtſchatka to New Britain, diſcovered by Dampier in 1700, and which lies in the 4th or 5th degree of ſouth latitude, the ocean has encroached on theſe coaſts to the extent of 400 leagues; and, of courſe, that the eaſtern bounds of the Old Continent ſtretch not ſo far as they did formerly; for, it is remarkable, that New Britain and Kamtſchatka, which are the moſt advanced lands to the eaſt, lie under the ſame meridian. Beſides, all countries extend fartheſt from north to ſouth. Kamtſchatka makes a points of about 160 leagues from north to ſouth, and this point, the eaſtern coaſt of which is waſhed by the Pacific Ocean, and the other by the mediterranean above deſcribed, is divided from north to ſouth by a chain of mountains. The lands of Japan and of Jeſſo form another territory between the ocean and the ſea of Corea, extending from north to ſouth more than 400 leagues; and the direction of the chains of mountains in Jeſſo and Japan muſt be from north to ſouth; becauſe, in this direction, they extend 400 leagues; but, from weſt to eaſt, they exceed not 50 or 60. Thus, Kamtſchatka, Jeſſo, and the eaſtern part of Japan, ought to be conſidered as contiguous lands, lying in a direction from north to ſouth: and, following the

the ſame direction, we find, after the point of Cape Ava in Japan, the iſland of Barnevelt, and three other iſlands, ſituated in a line from north to ſouth, and extending about 100 leagues. We next meet with three iſlands, called Callanos, and, after theſe, the Ladrone iſlands, to the number of 14 or 15, all ſtretched in a line from north to ſouth, the whole occupying a ſpace of 300 leagues in length; and the broadeſt part of theſe iſlands, from eaſt to weſt, exceeds not 8 leagues. From theſe facts, I am led to conclude, that Kamtſchatka, Jeſſo, the eaſt part of Japan, the iſlands of Barnevelt, the Callanos, and the Ladrones, are a continuation of the ſame chain of mountains, and the remains of an ancient country, which has been gradually corroded and covered with the ſea. All theſe countries appear to be nothing but mountains, of which the iſlands are the peaks or points, the low-lands being occupied by the ocean. Hence, what is related in the *Lettres Edifiantes* muſt be true; and, in fact, a number of iſlands, called the New Philippines, has been diſcovered in the very ſituation in which P. Gobien ſuppoſed them to lie: and it cannot be doubted, that the moſt eaſterly of theſe New Philippines are a continuation of the chain of mountains which compoſe the Ladrones; for theſe eaſtern iſlands, to the number of eleven, lie in a line from north to the ſouth, extending in length more than 200 leagues; and, in breadth,

breadth, the largeſt of them exceeds not eight leagues.

But theſe conjectures may ſeem too bold, on account of the great diſtances between the iſlands in the neighbourhood of Cape Ava, of Japan, and of the Callanos, between theſe iſlands and the Ladrones, and between the Ladrones and the New Philippines, the firſt interval being about 160 leagues, the ſecond 50 or 60, and the third near 120. But it ought to be conſidered, that chains of mountains often extend much farther below the waters of the ocean; and that theſe intervals are nothing when compared to the extent of land, from ſouth to north, in theſe iſlands or mountains, which, beginning at the interior part of Kamtſchatka, is more than 1100 leagues. But, though this idea concerning the quantity of land gained by the ocean on the eaſtern parts of the Old Continent, and the continuation of the mountains, ſhould be rejected, ſtill it muſt be acknowledged, that Kamtſchatka, Jeſſo, Japan, the iſlands of Rois, Formoſa, Vaif, Baſha, Babuyane, Lucca, Mindano, Gilolo, &c. and, laſtly, New Guinea, which extends to New Britain, and is ſituated under the ſame meridian as Kamtſchatka, form a ſtretch of country of more than 2200 leagues, with ſmall interruptions, the greateſt of which exceeds not, perhaps, 20 leagues; ſo that the ocean has ſcooped out an immenſe bay from the interior parts of the eaſtern continent, which begins at Kamtſchatka,

ſchatka, and terminates at New Britain. This bay is interſperſed with numerous iſlands, and has all the appearances of being gained from the land. It is, therefore, probable, that the ocean, by its conſtant motion from eaſt to weſt, has gradually gained this great tract of country from the continent, and has formed ſeveral mediterraneans, as thoſe of Kamtſchatka, of Corea, of China, and perhaps the whole Indian Archipelago; for the land and water are ſo blended together in this region, that it evidently appears to have been a large country deſtroyed by inundations, of which only the eminences and mountainous parts are now to be ſeen, the lower grounds being entirely concealed under the waters of the ocean. This hypotheſis is farther confirmed by the ſhallowneſs of the ſea, and the figures of the innumerable iſlands, which ſeem to be nothing but the tops of mountains.

If we take a more particular ſurvey of theſe ſeas, we ſhall find, that the northern part of the Chineſe ſea forms itſelf into a great bay, which begins at the iſland of Fungma, and terminates at the frontiers of the province of Pekin, about 50 leagues from this capital of the Chineſe empire. The moſt advanced and narroweſt part of this bay is called the gulf of Changi. It is probable that this gulf, and part of the ſea of China, are encroachments of the ocean, and that the iſlands above deſcribed are the moſt elevated

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parts of the ancient country. Farther ſouth are the bays of Tonquin and of Siam, in the neighbourhood of which is the peninſula of Malacca, conſiſting of a long chain of mountains, that run from north to ſouth; and the Andaman iſlands, which form another chain of mountains, in the ſame direction, ſeem to be only a continuation of thoſe of Sumatra.

The ocean afterwards forms the great bay of Bengal; where it may be remarked, that the land of the peninſula of Indus makes a concave curve, towards the eaſt, nearly reſembling the great bay of the eaſtern continent, which ſeems to have been produced by the ſame cauſe, namely, the motion of the ſea from eaſt to weſt. In this peninſula are the mountains of Gates, which extend from north to ſouth; and the iſland of Ceylon appears to have been ſeparated from this part of the continent.

The Maldiva iſlands are only another chain of mountains ſtretching from north to ſouth. Then follows the Arabian gulf, which ſends off four branches or arms; the two largeſt are on the weſt coaſts, and the two ſmalleſt on the eaſt. The firſt arm on the eaſt coaſt is the bay of Cambaia, which extends not above 50 or 60 leagues; but it receives two conſiderable rivers, the Tapta and the Baroche or Mehi. The ſecond arm or bay on the ſame coaſt is remarkable for the rapidity and height of its tides, which alternately advance and retreat more than

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50 leagues. Into this bay fall ſeveral rivers, as the Indus, the Padar, &c. which have brought down ſand and mud in ſuch quantities as to elevate the bottom of the bay, and reduce it nearly to a perfect level. It is owing to this circumſtance that the tides extend to ſo great a diſtance. The firſt arm on the weſt coaſt is the Perſic gulf, which advances into the land above 250 leagues; and the ſecond is the Red Sea, which, reckoning from the iſland of Socotora, extends above 680 leagues. From the ſtraits of Ormuz and of Babelmandel, theſe two arms ſhould be conſidered as mediterranean ſeas: they are both, indeed, ſubjected to a flux and reflux; but this circumſtance is occaſioned by their vicinity to the equator, where the tides riſe higher than in other climates. Beſides, they are both very long and very narrow. The motion of the tides is more rapid in the Red Sea than in the Perſic gulf; becauſe the former is nearly three times as long, and equally narrow, as the latter; neither does it receive any river capable of reſiſting the tide: but the Perſic gulf receives three large rivers at its moſt advanced extremity. It is apparent, that the Red Sea has been formed by an irruption of the ocean; for the ſituation and ſimilarity in the direction of the coaſts on each ſide of the ſtraits of Babelmandel ſhow, that this paſſage has been cut by the waters.

At the extremity of the Red Sea lies that famous ſtrip of land called the Iſthmus of Suez, which

which is a barrier to the junction of the Red Sea with the Mediterranean. In the preceding article, I gave the reaſons which render it probable that the Red Sea is higher than the Mediterranean, and that, if the Iſthmus were cut, an inundation and increaſe of the latter would be the conſequence. It may here be added, that, though the ſuperior elevation of the Red Sea ſhould not be allowed, yet it is inconteſtible, that there are no tides in the Mediterranean near the mouths of the Nile. It is equally certain, that the tides in the Red Sea riſe ſeveral feet; and this circumſtance alone, on the ſuppoſition of the removal of the Iſthmus, would occaſion a great influx of water from the Red Sea into the Mediterranean. Beſides, Varenius, in his geography*, remarks, 'Oceanus Germanicus, 'qui eſt Atlantici pars, inter Friſiam et Hollan-'diam ſe effundens, efficit ſinum, qui, etſi parvus 'ſit reſpectu celebrium ſinuum maris, tamen et 'ipſe dicitur mare, alluitque Hollandiæ empo-'rium celeberrimum, Amſtelodamum. Non 'procul inde abeſt lacus Harlemenſis, qui etiam 'mare Harlemenſe dicitur. Hujus altitudo non 'eſt minor altitudine ſinus illius Belgici, quem 'diximus, et mittit ramum ad urbem Leidam, 'ubi in varias foſſas divaricatur. Quoniam ita-'que nec lacus hic, neque ſinus ille Hollandici 'maris inundant adjacentes agros, (de naturali 'conſtitutione loquor, non ubi tempeſtatibus

* Page 100.

'urgentur, propter quas aggeres facti sunt ;) patet inde, quod non sint altiores quam agri Hollandiæ. At vero Oceanum Germanicum esse altiorem quam terras hasce, experti sunt Leidenses, cum suscepissent fossam seu alveum ex urbe sua ad Oceani Germanici littora, prope Cattorum vicum perducere, (distantia est duorum milliarium) ut, recepto per alveum hunc mari, possent navigationem instituere in Oceanum Germanicum, et hinc in varias terræ regiones. Verumenimvero, cum magnam jam alvei portam perfecissent, desistere coacti sunt, quoniam tum demum per observationem cognitum est, Oceani Germanici aquam esse altiorem quam agrum inter Leidam et littus Oceani istius: Unde locus ille, ubi fodere desierunt, dicitur *Het malle Gat.* Oceanus itaque Germanicus est aliquantum altior quam sinus ille Hollandicus,' &c. As the German ocean, therefore, is higher than the sea of Holland, nothing prevents us from believing that the Red Sea may be higher than the Mediterranean. Herodotus and Diodorus Siculus mention a canal of communication between the Nile, the Mediterranean, and the Red Sea: And M. de l'Isle, in 1704, published a map, where he has laid down the termination of a canal in the east branch of the Nile, which he imagined to be a part of the canal which formerly joined that river to the Red Sea*. We meet with the same opinion

* See Mem. de l'Acad. des Sciences, annèe 1704.

in a book entitled *Connoiſance de l'Ancien Monde*; where the author, copying Diodorus Siculus, informs us, that this canal was begun by Neco King of Egypt; that Darius King of Perſia continued the work; that it was finiſhed by Ptolemy II. who conducted it to the city of Arſinoa; and that it could be ſhut and opened at pleaſure. I pretend not to deny theſe facts; but, I confeſs, they appear to be doubtful. I ſuſpect, that the violence and height of the tides in the Red Sea, would neceſſarily communicate their influence to the waters of the canal: At leaſt, it would require great precaution to prevent inundations, and to keep the canal in proper repair. Though we are told by hiſtorians that this canal was begun and finiſhed, they are ſilent as to its duration; and the remains of it, which are pretended ſtill to exiſt, are perhaps the only parts of it that ever were executed. This branch of the ocean has been denominated the *Red Sea*, becauſe, wherever there are madrepores or corals at the bottom, the water of it has the appearance of being red. The following deſcription of it is given in the *Hiſtoire Generale des Voyages** : ‘ Before leaving the Red ‘ Sea, D. Jean inquired into the cauſes which ‘ induced the ancients to give it this appellation: ‘ He recollected, that Pliny had delivered ſeve‘ ral opinions concerning the origin of this ‘ name. Some derived it from a King of that

* Tom. i. p. 198.

'country called *Erythros*, which, in the Greek 'language, ſignifies *Red*: Others imagined that 'the red colour was occaſioned by the reflection 'of the ſun from the ſurface of the water; and 'others affirmed that the water itſelf was 'red. The Portugueſe, who had made ſeve- 'ral voyages in that ſea, alledged, that the 'whole coaſt of Arabia was remarkably red; 'and that the duſt and ſand carried into the ſea 'by the winds tinged the water with the ſame 'colour.

'Dom Jean, who examined the nature of the 'water and of the coaſts, through their whole 'extent, with the moſt ſcrupulous attention, aſ- 'ſures us, that the waters of this ſea have no 'pecularity in their colour; and that the duſt 'and ſand, not being red themſelves, could not 'poſſibly communicate this colour to the water. 'The land on each ſide, he obſerves, is gene- 'rally brown; in ſome places, it is black, and, 'in others, white: At Suaquem, the coaſts of 'which the Portugueſe never viſited, there are 'three mountains ſtriped with red; but they 'conſiſt of hard rocks, and the neighbouring 'ground is of the uſual colour.

'The truth is, that this ſea is all of the ſame 'uniform colour, of which any man may ſatiſ- 'fy himſelf by drawing water from different 'parts. But, it muſt be acknowledged, that, in 'ſome places, it appears, by accident, to be red, 'and, in others, green and white. This phæ-

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'nomenon admits of the following explication. 'From Suaquem to Koſſir, which is an extent of '136 leagues, the ſea is filled with banks and 'rocks of coral; they are ſo called from their 'reſembling coral in form and colour ſo exact-'ly, that it is difficult to perceive the diſtinction: 'There are two kinds of them, the one is white, 'and the other extremely red. In many places, 'they are covered with a kind of gum, or viſcid 'ſubſtance of a green colour, and ſometimes of 'a deep orange. Now, the water of this ſea is 'ſo tranſparent, that the bottom is viſible at the 'depth of twenty fathoms, eſpecially from 'Suaquem to the extremity of the gulf; and 'hence the water aſſumes, in appearance, the co-'lour of the bodies which it covers. When, 'for example, the rocks are overlaid with a 'green gum, the water above them appears to 'be green; when the bottom is ſand alone, the 'ſuperincumbent water ſeems to be white; and, 'when the rocks are covered with coral, the 'water above them appears to be reddiſh. But, 'as the rocks of this colour are more frequent 'than the green or white, Dom Jean concludes, 'that the Arabic Gulf has, from this circum-'ſtance, obtained the name of the Red Sea. 'He was the more ſatisfied with this diſcovery, 'becauſe the method he employed in the inve-'ſtigation of it left no room for heſitation or doubt. In ſuch places as were not deep enough to allow his veſſel to ſail, he faſtened

‘ pinks oppoſite to the rocks; and the ſailors ‘ were enabled to execute his orders, at more ‘ than half a league from the rocks, without be‘ ing immerſed above the middle of their bodies. ‘ In thoſe places where the water appeared red, ‘ the greateſt part of the ſtones and pebbles they ‘ brought up were of the ſame colour; where ‘ the water appeared green, the ſtones were ‘ green alſo; and where the water appeared ‘ white, the bottom was a pure white ſand.’

From the entrance to the Red Sea, at Cape Gardafu, to the Cape of Good Hope, the direction of the coaſt is pretty equal, and the ſea forms no bay of any note. There is, indeed, a ſmall ſcoop on the coaſt of Melinda, which, if the Iſland of Madagaſcar were united to the continent, might be conſidered as a part of a large bay. This iſland, it is true, though ſeparated by the ſtraits of Mozambique, appears to have formerly belonged to the continent; for, in this ſtrait, there are high ſands of great extent, eſpecially on the Madagaſcar coaſt, which render the open part of it very narrow.

From the Cape of Good Hope to Cape Negro, on the weſt coaſt of Africa, the land lies in the ſame direction; and the whole of it ſeems to be a chain of mountains: It is, at leaſt, a very elevated country, and, though more than 600 leagues in length, it is furniſhed with no rivers of any conſideration, except one or two, which are known no farther than their mouths.

mouths. But the coaſt, above Cape Negro, makes a large curve; and the land, along this curve, appears to be lower than that of the reſt of Africa: It is watered by ſeveral great rivers, the largeſt of which are the Coanza and the Zaire. From Cape Negro to Cape Gonſalvez, are the mouths of 24 conſiderable rivers; and the ſpace between theſe two capes, reckoning along the ſhore, is about 420 leagues. We would be tempted to think, that the ocean has encroached on theſe low lands of Africa, not by its natural motion from eaſt to weſt, which could have no influence in producing this effect, but by the facility with which it might have undermined and ſurmounted them. From Cape Gonſalvez to Cape Trois-pointes, the ocean forms an open bay, which preſents nothing remarkable, except a very advanced point nearly in the middle of it, called *Cape Formoſa*: It likewiſe contains, in the ſouthern part of it, the iſlands of Fernandpo, St. Thomas, and Prince's Iſland. Theſe iſlands appear to be a continuation of a chain of mountains ſituated between Rie del Rey, and the river Jamoer. From Cape Trois-pointes to Cape Palmas, the ocean runs a little in upon the land; and from Cape Palmas to Cape Tagrin, there is nothing worthy of remark. But, beyond Cape Tagrin, there is a ſmall bay in the country of Sierra-Leona; and a little farther, there is another, in which are ſituated the iſlands of Biſagas. We after-

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wards meet with Cape Verd, which projects far into the sea, and of which the islands of the same name appear to be a continuation; or, rather, they seem to be a continuation of Cape Blanc, which is a more elevated country, and stretches still farther into the ocean. We next come to a mountainous and dry coast, which commences at Cape Blanc, and terminates at Cape Bajador: The Canary islands seem to be a continuation of these mountains. Lastly, between Africa and Portugal, is a large open bay, in the middle of which are the celebrated Straits of Gibraltar. The ocean pours its waters, with great rapidity, through this strait into the Mediterranean. This sea runs into the interior parts of the land near 900 leagues, and gives rise to many objects worthy of remark. *1st*, It has no perceptible tides, except in the Gulf of Venice; and a small flux and reflux have been alledged to take place at Marseilles and on the coast of Tripoli. *2d*, It contains many large islands, as Sicily, Sardinia, Corsica, Cyprus, Majorca, &c. and Italy, which is one of the most extensive peninsula's in the world: It is likewise adorned with a rich Archipelago, or rather, it is from the Mediterranean Archipelago that all other collections of islands have acquired that appellation. But this Archipelago appears to belong more properly to the Black Sea than to the Mediterranean; and it is probable, that the country of Greece was partly covered with the Black Sea,

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which runs into the ſea of Marmora, and from that into the Mediterranean.

It has been alledged, that a double current runs through the Straits of Gibraltar; one ſuperior, which carries the waters from the ocean into the Mediterranean, and another inferior, which carries the waters from the Mediterranean back to the ocean. But this notion is falſe, and contrary to the known laws of hydroſtatics. Oppoſite currents have been aſcribed to ſeveral other ſtraits, as the Boſphorus, the ſtraits of Sunda, &c.; and Marſilli has related many experiments tending to prove the exiſtence of a ſuperior and inferior current in the Boſphorus. Theſe experiments, however, muſt have been fallacious; for ſuch a phænomenon is repugnant to the nature and motion of fluids. Beſides, Greaves, in his *Pyramidographie*, has demonſtrated by accurate experiments, that there are no oppoſite currents in the Boſphorus. Marſilli and others may have been deceived by the regorging of the water near the ſhores, which takes place in the Boſphorus, in the ſtraits of Gibraltar, and in all rapid rivers, and which often produces a motion oppoſite to that of the principal current.

Let us now briefly run over the coaſts of the New Continent. We ſhall begin with Cape Hold-with-hope, which is ſituated in the 73d degree of North Latitude. This is the moſt northerly point of land in New Greenland, and is

is diſtant from Cape North in Lapland about 160 or 180 leagues. From this cape the coaſt of Greenland might be traced to the polar circle, where the ocean forms a large ſtrait between Iceland and Greenland. Some maintain, that this country in the neighbourhood of Iceland is not the Ancient Greenland, formerly poſſeſſed by the Danes as a dependent province. Its inhabitants were civilized Chriſtians, who had biſhops, churches, and a number of towns proportioned to their trade. The Danes had a communication with them as eaſy, and as frequent, as the Spaniards with the Canary iſlands: There ſtill exiſts, it is ſaid, laws and regulations with regard to the government of this province, and theſe not of a very ancient date. However, without forming any conjectures how this country came to be abſolutely loſt, we find not in New Greenland the leaſt veſtige of what is here related. They are mere ſavages: They have no buildings: There is not a word in their language that has the ſmalleſt affinity to the Daniſh tongue; and there is not a ſingle circumſtance from which we can infer it to be the ſame country. It is even almoſt a deſert, and is covered with ſnow and ice the greateſt part of the year. But, as theſe lands are of vaſt extent, and, as the coaſts have been little frequented by modern navigators, they may have miſſed the place occupied by the deſcendants of theſe poliſhed people; or the increaſe of the ice

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in this ſea may now, perhaps, prevent all acceſs to them. If, however, maps can be truſted, the whole coaſt of this country is known: It forms a large peninſula, at the extremity of which are the two ſtraits of Frobiſher and of Frieſland, where the cold is exceſſive, although they are not farther north than the Orkneys, that is, about 60 degrees.

Between the weſt coaſt of Greenland, and that of Labrador, the ocean forms a gulf, and then a large mediterranean, which is the coldeſt of all ſeas, and its coaſts are little known. In purſuing this gulf, we meet with Davis's ſtrait, which leads to the Chriſtian ſea, which laſt terminates in Baffin's bay, through which there appears to be an outlet into Hudſon's bay. The ſtrait of Cumberland, which, like that of Davis, may lead into the Chriſtian ſea, is more narrow, and more ſubject to be frozen. Hudſon's ſtrait, though much farther ſouth, is alſo frozen for ſome part of the year: And it is remarkable, that the tides are very high in thoſe ſeas and ſtraits, although no tides take place in the inland ſeas of Europe, as the Baltic and Mediterranean. This difference ſeems to be occaſioned by the motion of the ſea from eaſt to weſt, which produces high tides in ſtraits oppoſite to the current of the waters, or whoſe mouths open to the eaſt. But, in thoſe of Europe, which open to the weſt, there are no tides. The ocean, by its general movement, ruſhes into the former, but

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flies from the latter; and this is the reaſon why the tides are ſo violent in the ſeas of China, Corea, and Kamtſchatka.

In ſailing down Hudſon's bay towards Labrador, there is a narrow opening, 30 leagues of which Davis traverſed in 1586, and traded with the inhabitants. But no attempts have hitherto been made to diſcover the whole of this arm of the ſea. We know nothing of the neighbouring country, but the land of the Eſquimaux. Fort Ponchartrin is the only ſettlement, and the moſt northerly part of this country; and it is ſeparated from the iſland of Newfoundland by the ſmall ſtrait of Belleiſle, which is little frequented. As the eaſtern coaſt of Newfoundland has the ſame direction with that of Labrador, this iſland appears to have been formerly a part of the continent, in the ſame manner as Iſle-royal ſeems to have been detached from Acadia. The bottoms of the great bank, and of the leſſer banks on which the cod-fiſhery is carried on, are not deep; but, as they ſhelve a great way under water, they produce violent currents. Between Cape Breton and Newfoundland, there is a pretty large ſtrait, which is the mouth of a ſmall mediterranean, called the *Gulf of St. Laurence.* It ſends off a branch, which extends a conſiderable way into the country, and appears to be only the mouth of the river of that name. In this arm of the ſea the tides are very perceptible; and, even at Quebec,

Quebec, which is farther up the country, the waters riſe ſeveral feet. Leaving the gulf of St. Laurence, and following the coaſt of Acadia, we meet with a ſmall gulf called *Boſton-Bay*, which is of a ſquare figure, and advances a little way only into the land. But, before we purſue this coaſt any farther, it is worthy of remark, that, from Newfoundland to Guiana, the ocean forms an immenſe bay, that runs in upon the land as far as Florida, which is more than 500 leagues. This bay is ſimilar to that of the Old Continent above deſcribed, where the ocean, after forming a large gulf between Kamtſchatka and New Britain, gives riſe to a great mediterranean, which comprehends the ſea of Kamtſchatka, of Corea, of China, &c. In the ſame manner, in the New Continent, the ocean, after forming a large gulf between Newfoundland and Guiana, gives riſe to a great mediterranean, extending from the Antilles to Mexico; which confirms what we have advanced concerning the motion of the ſea from eaſt to weſt: For it appears that the ocean has gained as much territory on the eaſt coaſt of America as on the eaſt coaſt of Aſia. Beſides, theſe great gulfs in each continent lie under the ſame degrees of latitude, and are nearly of equal extent. Such ſingular relations, it would appear, muſt have been produced by the ſame cauſe.

If we examine the poſition of the Antilles, beginning with the iſland of Trinidad, which is the

the fouthmoft, it is impoffible to doubt but that Trinidad, Tobago, the Granades, St. Vincent, Martinico, Marygalante, Antego, Barbadoes, and all the adjacent ifles, once formed a chain of mountains, which extended from fouth to north, like Newfoundland and the country of the Efquimaux. Farther, the direction of the Antilles from eaft to weft, if we begin with Barbadoes, and pafs on to St. Bartholomy, Porto-Rico, St. Domingo, and Cuba, is nearly the fame with the coafts of Cape Breton, Acadia, and New England. All thefe iflands lie fo contiguous, that they may be regarded as a continued belt of land, and as the moft elevated parts of a country now occupied by the fea. Moft of them are nothing but the tops of mountains; and the fea between them and the continent is a true mediterranean, in which the tides are not much more perceptible than in our Mediterranean, although the ftraits between the iflands are directly oppofed to the motion of the fea from eaft to weft, which fhould contribute to raife the tides in the gulf of Mexico. But, as this gulf is very broad, the waters elevated by the tide when expanded over a large furface, hardly produce any fenfible change upon the coaft of Louifiana and feveral other places.

Both the Old and New Continents, therefore, appear to have been encroached upon by the ocean in the fame latitudes: Both are furnifhed with a great mediterranean, and a vaft number

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of iſlands, which likewiſe lie nearly in the ſame latitudes. The only difference is, that the Old Continent, being much larger than the New, has a mediterranean on its weſt coaſt, to which the New Continent has nothing analogous. But both ſeem to have undergone ſimilar revolutions. Theſe revolutions are greateſt near their middle parts, or between the tropics, where the motion of the ſea is moſt violent.

The coaſts of Guiana, from the mouth of the river Oronoko to that of the Amazons, exhibit nothing remarkable. But the Amazons, which is the largeſt river in the univerſe, forms a conſiderable ſheet of water near Coropa, before it diſcharges itſelf into the ſea by the two mouths which ſurround the iſland of Caviana. From the mouth of the Amazons to Cape St. Roche, the river runs almoſt ſtraight eaſt; from Cape St. Roche to Cape St. Auguſtine it runs ſouth, and from Cape St. Auguſtine to the bay of All Saints, it runs weſtward in ſuch a manner that this part of Braſil projects conſiderably into the ocean, which is directly oppoſite to a ſimilar projection of the African coaſt. The bay of All Saints is a ſmall arm of the ſea, which advances about 50 leagues into the land, and is much frequented by navigators. From this bay to Cape St. Thomas, the coaſt runs ſtraight ſouth, and from thence, in a ſouth-weſt direction, to the mouth of the Plata, where an arm of the ſea projects about 100 leagues into the land.

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From this river, to the ſouthern extremity of America, the ocean forms a large bay, which is terminated by Falkland Iſland, Cape Aſſumption, and other lands bordering on Terra del Fuego. At the bottom of this bay is the ſtrait of Magellan, the longeſt in the univerſe, and where the tides riſe very high. Beyond this is the ſtrait of La Maire, which is much ſhorter; and, *laſtly*, Cape Horn, which is the ſouth point of America.

On the ſubject of points or head-lands, it is remarkable, that they all regard the ſouth, and that moſt of them are cut by ſtraits which run from eaſt to weſt. The point of South America regards the Arctic Pole, and it is cut by the ſtrait of Magellan: That of Greenland, which likewiſe has a ſouthern aſpect, is cut from eaſt to weſt by the ſtrait of Frobiſher: That of Africa regards alſo the ſouth, and, beyond the Cape of Good Hope, are banks and ſhoals which appear to have been ſeparated from it: That of the peninſula of India is cut by the ſtrait between it and the iſland of Ceylon; and, like all others, projects ſouthward. Theſe are facts; but we are unable to give any explication of them.

From Terra del Fuego, all along the weſt coaſt of South America, the ocean makes conſiderable advances into the land; and this coaſt ſeems to follow exactly the direction of the high mountains which traverſe this part of the continent, from

from south to north, from the Equator to the Arctic Pole. Near the Line, the ocean forms as large bay, extending from Cape St. Francois to Panama, that famous isthmus, which, like that of Suez, prevents the junction of the two seas. If these two necks of land were removed, both the Old and the New Continent would be divided into two distinct portions. From Panama to California, there occurs nothing worthy of remark. Between the peninsula of California and New Mexico, is a long arm of the ocean, called the *Vermilion Sea*, which is more than 200 leagues long. In fine, the west coast of California has been traced to the 43d degree of latitude. It was in this latitude that Drake, who first discovered the land to the north of California, and which he called *New Albion*, was obliged, by the rigour of the cold, to change his course, and to anchor in a small bay which bears his name; so that the countries beyond the 43d or 44th degree, in this part of the globe, are as little known as those of North America beyond the 48th degree, which is inhabited by the Moozemleki, and the 51st, which is inhabited by the Assiniboils. The territory of the former savages extends much farther west than that of the latter. All beyond, for 1000 leagues in length, and as much in breadth, is totally unknown, unless the Russians, as they pretend, have made some discoveries by departing from

Kamtſchatka, and viſiting the eaſtern coaſts of North America.

The ocean, then, ſurrounds the whole globe, without interruption, and we may ſail round it by taking our departure from the ſouth point of America. But we are ſtill uncertain whether the ocean ſurrounds, in the ſame manner, the north part of the globe; and all the navigators, who have attempted to go from Europe to China by the north-eaſt or north-weſt, have equally failed in their enterpriſes.

Lakes differ from mediterraneans; the former derive no water from the ocean; on the contrary, when they communicate with ſeas, they are conſtantly diſcharging water into them. Thus the Black Sea, which ſome geographers have regarded as a branch of the Mediterranean, and, of courſe, as an appendage of the ocean, is only a lake; becauſe, in place of receiving any ſupplies from the Mediterranean, its waters run with rapidity through the Boſphorus into the lake called the Sea of Marmora, and from thence through the ſtraits of the Dardanelles into the Grecian Sea. The Black Sea is about 250 leagues long, and 100 broad: It receives a number of large rivers, as the Danube, the Nieper, the Don, the Boh, the Donjec, &c. The Don, which unites with the Donjec, before it arrives at the Black Sea, forms a lake called the *Palus Meotis*, which is more than 100 leagues in length, and from 20 to 25 in breadth. The Sea

of

of Marmora, which is below the Black Sea, is a lake ſmaller than the Palus Meotis, being not above 50 leagues long, and 8 or 9 broad.

It is related by ſome of the ancients, and particularly by Diodorus Siculus, that the Euxine, or Black Sea, was originally a great river or lake, and had no communication with the Greek Sea; but that its waters were, in the courſe of time, ſo greatly augmented by the rivers which fall into it, that they forced a paſſage, firſt by the iſlands of Cyanea, and then by the Helleſpont. This opinion has great probability on its ſide; and, I think, it is no difficult matter to explain how the operation was effected: For, ſuppoſing the bottom of the Black Sea to have been formerly much lower than it is now, the mud and ſand carried down by the rivers would gradually raiſe it, till the ſurface of the water was elevated above that of the land, and then the water would neceſſarily find a paſſage for itſelf: and, as the rivers continue ſtill to tranſport ſand and earth, and as, at the ſame time, the quantity of water in the rivers diminiſhes in proportion as the mountains from which they ſpring are lowered, it may happen, in the courſe of ages, that the Boſphorus will again be filled up. But, as effects of this nature depend on many cauſes, we muſt content ourſelves with ſimple conjectures. Mr. Tournefort, on the authority of the ancients, ſays, that the Black Sea, which receives the waters of a great part of Eu-

rope and Aſia, after being conſiderably augmented, opened to itſelf a paſſage by the Boſphorus, and either formed the Mediterranean, or increaſed its waters to ſuch a degree, that they forced a paſſage to the ocean through the ſtraits of Gibraltar; and that the iſland of Atalantis, mentioned by Plato, was, on this occaſion, totally overflowed. This notion cannot be ſupported; for the ocean runs into the Mediterranean, and not the Mediterranean into the ocean. Beſides, M. Tournefort has not combined two eſſential facts, though he has mentioned both of them. The firſt is, that the Black Sea receives 9 or 10 rivers, each of which furniſhes more water than is diſcharged by the Boſphorus; and the ſecond, that the Mediterranean does not receive more water from rivers than the Black Sea, though it be ſeven or eight times larger; and what it receives from the Boſphorus is not the tenth part of what falls into the Black Sea. How, therefore, could this tenth part of the water that falls into a ſmall ſea, produce not only a larger ſea, but augment its waters to ſuch a degree as would enable it to break down the iſthmus of Gibraltar, and overwhelm an iſland of greater extent than the whole of Europe? It is eaſy to perceive that M. Tournefort has not ſufficiently conſidered this matter. The Mediterranean derives from the ocean at leaſt ten times the quantity of water it receives from the Black Sea; for the narroweſt part of the

Boſphorus

Bofphorus exceeds not 800 paces, while that of the ftraits of Gibraltar is more than 5000; and fuppofing the velocities of both to be equal, ftill the water in the ftraits of Gibraltar is by much the deepeft.

M. Tournefort, who ridicules Polybius for predicting that the Bofphorus will in time be filled up, has not attended fufficiently to circumftances, otherwife he would not have pronounced the impoffibility of fuch an event. Muft not the Black Sea, which conftantly receives the fand and mud of eight or ten large rivers, gradually fill up? Muft not the winds and the natural current of the waters continually tranfport part of thefe matters into the Bofphorus? It is, therefore, extremely probable, that, in the courfe of ages, the Bofphorus will be choaked up, when the quantity of water difcharged by the rivers into the Black Sea fhall be greatly diminifhed. Now, the rivers are diminifhing daily, becaufe the mountains, which collect the dews, and give rife to the rivers, are continually decreafing.

The Black Sea receives more water from rivers than the Mediterranean; and M. Tournefort obferves, on this fubject, 'That the greateft 'rivers in Europe fall into this fea by means 'of the Danube, into which are difcharged the 'rivers of Suabia, Franconia, Bavaria, Auftria, 'Hungary, Moravia, Corinthia, Croathia, Bothnia, Servia, Tranfylvania, and Wallachia: the 'rivers of Black Ruffia and of Podolia fall like-

'wise into the same sea by means of the Niester; 'those of the southern and eastern parts of Poland, of the northern part of Muscovy, and of 'the country of the Cossacks, fall into it, either 'by the Nieper or Boristhenes; the Tanais and 'the Copa empty themselves into the Black Sea 'by the Cimmerian Bosphorus; the rivers of 'Mingrelia, the principal of which is the Phasis, 'also discharge their contents into this sea, and 'likewise the Casalmac, the Sangaris, and other 'rivers of Asia Minor which take a northern 'course: but the discharge through the Thracian Bosphorus, which is the only outlet from 'the Black Sea, is not comparable to that of 'any one of these great rivers *.'

All these facts demonstrate the great quantity of water carried off by evaporation; and it is owing to this circumstance that the ocean constantly runs into the Mediterranean by the straits of Gibraltar. It is difficult to ascertain the quantity of water received by any sea; it requires an exact knowledge of the breadth, depth, and velocity of all the rivers that fall into it, of their augmentation and diminution in different seasons of the year, and of the quantity which the sea loses by evaporation. This last is the most difficult to determine; for supposing evaporation to be proportioned to the surfaces, it will be greater in a warm than in a cold climate. [Be]sides, water mixed with salt and bitumen eva-

* See voyage du Levant de Tournefort, vol. ii. p. 123.

porates

porates more ſlowly than freſh water; a ſea ſubject to great agitation evaporates more quickly than a calm ſea; and a difference in the depth has alſo ſome effect. In fine, ſo many particulars are included in the theory of evaporation, that it is not poſſible to make an exact eſtimation of its quantity.

The water of the Black Sea is leſs clear and leſs ſalt than that of the ocean. There are no iſlands in it; and its tempeſts are more violent and more dangerous than thoſe of the ocean; becauſe its waters, being extended in a baſin which has but an inconſiderable outlet, move, when agitated in a kind of whirlpools, which beat upon all ſides of a veſſel with an inſupportable violence *.

After the Black Sea, the greateſt lake in the world is the Caſpian Sea, which extends from ſouth to north about 300 leagues, and its mean breadth exceeds not 50. This lake receives the Wolga, beſides ſeveral other conſiderable rivers, as the Kur, the Faie, and the Gempo. But, what is ſingular, it receives not one river from the eaſt coaſt; the country on that ſide is a ſandy deſert, which remained, till lately, altogether unknown. The Czar Peter I. ſent engineers to make a chart of the Caſpian Sea. It had been repreſented as round by former geographers; but it is very long and very narrow. Its eaſtern coaſt, and the neighbouring country, were

* See voyages de Chardin, p. 142.

entirely unknown; even Lake Aral, which is about 100 leagues eaſt of the Caſpian, was either not known to exiſt, or was conſidered as a part of this ſea. Thus, before the diſcoveries of the Czar, there was in this region an unknown country of 300 leagues in length, and 100 or 150 in breadth. Lake Aral is nearly oblong, and about 90 or 100 leagues long, and 50 or 60 broad. It receives the Sideroias and the Oxus, two large rivers; but, like the Caſpian, it has no outlet for diſcharging its waters; and, as the Caſpian receives no rivers from the eaſt, Lake Aral, on the contrary, receives none from the weſt. Hence, it is preſumable, that theſe two formerly conſtituted but one lake; and the rivers being gradually choaked up, the country between them would neceſſarily be covered with ſand. There are ſome ſmall iſlands in the Caſpian; and its waters are much freſher than thoſe of the ocean. Storms, in this ſea, are exceedingly dangerous; and it affords not navigation to large veſſels, on account of ſhoals, ſand-banks, and rocks concealed under the ſurface. 'The largeſt veſſels employed on the 'Caſpian,' ſays Pietro della Valle*, 'along the 'coaſts of the province of Mazanda in Perſia, 'where ſtands the town of Ferhabad, although 'they be called *ſhips*, are no better than our tar'tanes: their ſides are high; they draw little wa'ter, and are flat-bottomed. They are built of this

* Tom. iii. p. 235.

'construction, not only becaufe this fea is shal-
'low near the coafts, but becaufe it is full of
'fhoals and fand-banks; fo that no other veffels
'could be ufed with fafety. I was furprifed
'to fee no fifhing carried on at Ferhabad, ex-
'cept falmons at the mouth of the river, a
'bad kind of fturgeon, and other frefh water
'fifhes of no value. I attributed this to their
'ignorance of navigation and of the art of fifh-
'ing, till I was informed by the Cham of Efter-
'abad, that this fea, at the diftance of 20 or 30
'miles from the fhore, is fo fhallow, that nets
'could not be ufed with advantage; and that
'the fame reafon accounted for the conftruction
'of their veffels, which carry no cannon, becaufe
'the Cafpian is not infefted with pirates.'

Struys, Avril, and others, affirm, that, in the neighbourhood of Kilan, there are two gulfs, which fwallow up the waters of the Cafpian, and carry them, by fubterraneous paffages, into the Perfic Gulf. De Fer, and other geographers, have laid down thefe gulfs in their maps, though we are affured by the Czar's envoys, that they have no exiftence*. The fact, with regard to the willow leaves found on the Perfic Gulf, and which are alledged by the fame authors to be tranfported from the Cafpian Sea, becaufe no willows grow near the Perfic Gulf, appears to be equally improbable, as the fubterraneous paffages, which Gemelli Careri, as well

* See Mem. de l'Acad. des Sciences, année 1721.

as

as the Ruſſians, maintain to be altogether imaginary. Beſides, the Caſpian is about a third leſs than the Black Sea, which laſt alſo receives more water by rivers; evaporation, therefore, is alone ſufficient to carry off all its adventitious waters, without the aſſiſtance of imaginary gulfs, or ſubterraneous paſſages.

There are lakes, or ſeas, which neither receive nor diſcharge rivers; there are others which both receive and diſcharge, and others which only receive. The Caſpian, Lake Aral, and the Dead Sea, are of the laſt kind: In Aſia Minor, there is a ſmall lake of the ſame ſpecies: There is another ſtill larger in Perſia, upon which the city of Marago is ſituated: It is of an oval figure, and about 10 or 12 leagues long, and 6 or 7 broad: It receives the Tauris, which is not a very conſiderable river. If to theſe we add a ſmall lake of the ſame nature in Greece, 12 or 15 leagues from Lepanto, we have an enumeration of all the known lakes in Aſia which belong to this ſpecies. In Europe, there is not a ſingle one of any conſideration. There are ſeveral ſmall lakes of this kind in Africa, as thoſe which receive the rivers Ghir, Zez, Touguedot, and Taſilet. Theſe four lakes lie at no great diſtance from one another, and are ſituated on the frontiers of Barbary, near the deſert of Zaara. There is another in the province of Kovar, which receives the river that runs through the country of Berdoa. In

North

North America, which abounds with lakes, there are none of this kind, except two ſmall collections of water formed by brooks, the one near Guatimapo, and the other ſome leagues from Realnuevo, both in Mexico. But in Peru there are two contiguous lakes, one of which, Lake Taticaca, is very large, and receives a river which riſes near Cuſco; but it gives riſe to no river. There is a ſmall lake in Tucuman, which receives the river Salta; another, in the ſame country, of greater extent, receives the Santiago; and three or four between Tucuman and Chili.

Thoſe lakes, which neither receive nor give riſe to any river, are more numerous than the kind juſt mentioned. They are a ſpecies of ſwamps, which collect the rain water; or, they may originate from ſubterraneous waters that iſſue in the form of ſprings in low grounds, from which there is no fall to carry them off. Thoſe rivers that overflow may alſo leave ſtagnating waters upon the land, which remain a conſiderable time, and are occaſionally recruited by ſubſequent inundations. Salt lakes may ſometimes be produced by inundations from the ſea, as that at Harlem, and ſeveral others, in Holland, to which no other origin can be aſcribed. The ſea, likewiſe, by abandoning certain lands, may have left lakes in the low grounds of particular countries, and which continue to be maintained by the rains. Of this kind, there are

are ſmall lakes in Europe, as in Ireland, in Jutland, in Italy, in the country of the Griſons, in Poland, in Muſcovy, in Finland, and in Greece: But all theſe are of little conſideration. In Aſia, near the Euphrates, in the deſert of Irac, there is one above 15 leagues long; another in Perſia, nearly of the ſame extent, upon which are ſituated the towns of Kelat, Tetuan, Vaſtan, and Van; a ſmall one in Chorazan, near Ferrior; another in Independent Tartary, called *Lake Levi;* two in Muſcovite Tartary; one in Cochinchina; and, in fine, a pretty large one not far from Nankin. This laſt, however, communicates with the neighbouring ſea by a canal of conſiderable extent. In Africa, there is a ſmall lake of this ſpecies in the kingdom of Morocco; another near Alexandria, which appears to have been left by the ſea; another, 8 or 10 leagues long, formed by the rain-water, in the deſert of Azarad, about the 30th degree of latitude; another, ſtill larger, upon which is ſituated the town of Gaoga, under the 27th degree; another, but much ſmaller, near the town of Kanum, under the 30th degree; one near the mouth of the river Gambia; ſeveral others in Congo, about the 2d or 3d degree of ſouth latitude; two others in the country of the Caffres; one of them, called *Lake Ruſumbo,* is not very extenſive; and the other, which lies in the province of Arbuta, is perhaps the largeſt of this kind, being about 25 leagues long, and 7 or

8 broad;

8 broad: There is likewiſe one of theſe lakes near the eaſt coaſt of Madagaſcar, about the 29th degree of ſouth latitude.

In America, there is one of theſe lakes ſituated in the middle of the peninſula of Florida, which has an iſland called *Serrope* in its centre. The lake near the town of Mexico, which is round, and about 10 leagues in diameter, belongs likewiſe to this ſpecies. There is another ſtill more extenſive in New Spain, about 25 leagues from the eaſtern coaſt of the bay of Campeachy; and another, of ſmaller dimenſions, in the ſame country, near the coaſt of the South Sea. Some travellers have affirmed, that, in the interior parts of Guiana, there is a very large lake of this ſpecies, which they call *Golden Lake*, or *Lake Parima*; and they have given marvellous accounts of the riches of the neighbouring country, and of the great quantities of gold duſt found in this lake, which they alledge to be more than 400 leagues in length, and above 125 in breadth: No river, it is ſaid, either enters into or iſſues from it. Though this lake be laid down in ſeveral maps, its exiſtence is ſtill problematical.

But the moſt common and the moſt extenſive lakes are thoſe which both receive and give riſe to rivers: As they are exceedingly numerous, I ſhall only mention the largeſt, or the moſt remarkable of them. Beginning with Europe, we have, in Switzerland, the Lake of Geneva, that

that of Conſtance, &c. In Hungary, Lake Balaton, and another, of equal extent in Livonia, which ſeparates this province from Ruſſia; Lake Lapwert in Finland, which is very long, and divides into ſeveral branches, and Lake Oula, which is of a circular figure: In Muſcovy, Lake Ladoga, which is more than 25 leagues long, and above 12 broad; Lake Onega, which is equally long, but not ſo broad; Lake Ilmen; Lake Belozero, which is one of the ſources of the Wolga; Lake Iwan-Oſero, which is one of the ſources of the Don; and two other lakes, from which the river Vitzogda derives its origin: In Lapland, the lake from which iſſues the river Kimi; another, much larger, and ſituated near the coaſt of Wardhus; and ſeveral others of leſs note, which give riſe to the rivers Lula, Pitha, and Uma: In Norway, two lakes nearly of the ſame dimenſions with thoſe of Lapland: In Sweden, Lake Vener, which is as large as Lake Meller, upon which Stockholm is ſituated; and two leſs conſiderable, one near Elvedal, and the other near Lincopin.

In Siberia and in Muſcovite and Independent Tartary, there are a great number of theſe lakes, of which the principal are, the great lake Baraba, which is more than 100 leagues long, and the waters of which fall into the Irtis; the great lake Eſtraguel, the ſource of the Irtis; ſeveral leſſer ones, the ſources of the Jeniſca; the great lake Kita, the ſource of the Oby; another great

 lake,

lake, the ſource of the Angara; Lake Baical, which is more than 70 leagues long, and is formed by the river Angara; and Lake Pehu, the ſource of the Urack, &c. In China and Chineſe Tartary, we have Lake Dalai, the ſource of the great river Argus, which falls into the Amour; the lake of the Three Mountains, the ſource of the river Helum, which falls likewiſe into the Amour; the lakes of Cinhal, Cokmor, and Sorama, the ſources of the river Hoamho; two large lakes in the neighbourhood of Nankin, &c. In Tonquin is the Guadag, a lake of conſiderable magnitude. In India, we have Lake Chiamat, which is the ſource of the river Laquia, and lies near the ſources of the Ava, the Longenu, &c. This lake is more than 50 leagues long, and about 40 broad. The ſource of the Ganges is another lake; and one near Caſhmire gives riſe to the Indus, &c.

In Africa, there are Lake Cayar, and two or three others, near the mouth of the Senegal; Lake Guarda, and Lake Sigiſmus, which, together, make a triangular lake of 100 leagues long, and 75 broad, and contain a conſiderable iſland. It is in this lake that the Niger loſes its name, and, at its exit, aſſumes that of *Senegal*. In aſcending towards the courſe of this river, we meet with another pretty large lake called *Bournou*, where the Niger again changes its name; for the river that falls into this lake is called *Gambaru*. At the ſources of the Nile in Ethiopia,

pia, is the great lake Gambia, which is above 50 leagues long. On the coaſt of Guiney are alſo ſeveral lakes, which appear to have been originally formed by the ſea; and there are few others in Africa of any note.

North America is the country of lakes. The moſt extenſive of them are, Lake Superior, which is about 125 leagues long, and 50 broad; Lake Huron, which is near 100 leagues in length, and about 40 in breadth; Lake Illionois, which comprehending the bay of Puants, is nearly as extenſive as Lake Huron; Lake Erie and Lake Ontario, which, together, exceed 80 leagues in length, by 20 or 25 in breadth; Lake Miſtaſin, to the north of Quebec, is about 50 leagues long; Lake Champlain, to the ſouth of Quebec, is nearly of equal length; Lake Alemipigon, and Lake Chriſtinaux, both to the north of Lake Superior, are likewiſe conſiderable; the Lake of Aſſiniboils contains ſeveral iſlands, and is more than 75 leagues long: Beſides the Mexicon Gulf, there are two conſiderable lakes in that country; that called Nicaragua, in the province of the ſame name, is about 70 leagues in length.

Laſtly, in South America, there is a ſmall lake, the ſource of the Maragnon. A more extenſive one gives riſe to the river Paraguay: There are, beſides Lake Titicares, the waters of which fall into the river Plata, two leſſer ones, which diſcharge their waters into the ſame river;

ver; and ſome inconſiderable ones in the interior parts of Chili.

All lakes that give riſe to rivers, and all thoſe which occur in the courſe of rivers, or which border upon and diſcharge their waters into rivers, are not ſalt. Almoſt all thoſe, on the contrary, which receive rivers, but give riſe to none, are ſalt. This circumſtance ſeems to favour the opinion, that the ſaltneſs of the ſea is occaſioned by ſalts brought down from the land by the rivers; for we find ſalt does not evaporate; and, of courſe, all that is tranſported by the rivers remains in the ſea: Although the water of rivers appears to be freſh, it is well known, that it contains a ſmall quantity of ſalt, which, in the courſe of ages, might accumulate to ſuch a degree as would be ſufficient to produce the preſent ſaltneſs of the ſea, which muſt be continually augmenting. It is in this manner, I preſume, that the Caſpian, Lake Aral, and the Black Sea, have become ſalt. With regard to thoſe ſeas, which, like marſhes, or ſwamps, neither receive nor diſcharge rivers, they are either ſalt or freſh according to their origin. Thoſe in the neighbourhood of the ſea are commonly ſalt; and thoſe at a diſtance from it are freſh; becauſe the former have originated from inundations of the ſea, and the latter from freſh fountains.

The waters of the Dead Sea contain a great deal of the bitumen of Judæa, which is nothing but

aſphaltes; and, accordingly, this ſea is often termed the *Aſphaltic Lake.* The neighbouring land is impregnated with this bitumen: And many have imagined, that, like the Lake Avernus, no fiſhes could live in it, and that birds were ſuffocated in attempting to fly over it. But ſuch diſmal effects are produced by neither of theſe lakes; for both of them contain fiſhes, the birds fly over them in ſafety, and men bathe in them with impunity.

It is ſaid, that, in Bohemia, there is a lake, which has holes in it ſo deep, that they cannot be ſounded, and that, from theſe holes, there iſſue violent winds which ſweep over all Bohemia, and, in winter, raiſe into the air maſſes of ice of more than 100 pounds weight *. We are likewiſe told of a petrifying lake in Iceland; and Lake Neagh in Ireland poſſeſſes the ſame quality. But theſe petrifications are, doubtleſs, nothing but incruſtations ſimilar to thoſe produced by the waters at Arcueil.

* See Act. Leipſ. anno 1682, p. 246.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XII.

Of the Tides.

WATER, like other fluids, naturally defcends from the higher to the lower grounds, if not prevented by fome interpofed obftacle; and, after it has occupied the loweft fituation, it remains fmooth and tranquil, unlefs difturbed by fome foreign caufe. All the waters of the ocean are collected in the loweft places upon the furface of the earth; and hence the motions of the fea muft proceed from external caufes. The chief motion is that of the tides, which rife and fall alternately, and from which refults a general and perpetual motion, in all feas, from eaft to weft. Thefe two motions have an invariable relation to the mo-

tions of the moon. During the full and new moons, this motion from eaſt to weſt is moſt remarkable, as well as that of the tides, which ebb and flow, upon moſt coaſts, every 6½ hours: It is always high tide when the moon arrives at the meridian, either above or below the horizon of the place; and it is always ebb or low tide when the moon is at the greateſt diſtance from the meridian, or when it riſes and ſets. The motion from eaſt to weſt is perpetual; becauſe, when the tide is riſing, the whole ocean moves from eaſt to weſt, and puſhes weſtward an immenſe body of water; and the ebbing, or reflux, appears only to be owing to the ſmaller quantity of water which is then impelled towards the weſt. The flux, therefore, ought rather to be regarded as a ſwelling, and the reflux as the ſubſiding of the waters, which, in place of diſturbing the motion from eaſt to weſt, is the cauſe that produces and renders it perpetual; though this motion, for the reaſon already mentioned, is greater during the flux than the reflux.

This motion is attended with the following circumſtances: 1ſt, It is more ſenſible at the full and new moon than at the quadratures; it is likewiſe more violent in ſpring and autumn than in any other ſeaſon; and it is weakeſt at the ſolſtices. This phænomenon is occaſioned by the combined attractions of the moon and ſun. 2d, The direction and quantity of this motion

is

is often varied by the winds, eſpecially ſuch as blow conſtantly from the ſame quarter. Great rivers, in like manner, by diſcharging their water into the ſea, produce currents which often extend ſeveral leagues, and are ſtrongeſt when the direction of the wind correſponds with the general motion. Of this an example is afforded in the Pacific Ocean, where the motion from eaſt to weſt is conſtant, and very perceptible. 3*d*, It is worthy of remark, that, when one part of a fluid is moved, the motion is communicated to the whole: During the tides, therefore, a great part of the ocean is ſenſibly put in motion; and, conſequently, the whole ocean, from ſurface to bottom, is moved at the ſame time.

To render this more clear, let us attend to the cauſes which produce the tides. We formerly remarked, that the moon acted upon the earth by a force which ſome call attraction, and others gravity. This force penetrates the whole globe, is exactly proportioned to the quantity of matter, and decreaſes as the ſquares of the diſtances increaſe. Let us next examine what effects this force muſt produce upon the waters, when the moon comes to the meridian of any place. The ſurface of the water immediately under the moon is then nearer that planet than any other part of the earth; of courſe, that part of the ſea muſt be elevated towards the moon, and the ſummit of this eminence muſt be oppoſite to the moon's centre. To produce this eminence, the

waters upon the ſurface, as well as thoſe at the bottom, contribute their ſhare, in proportion to their diſtances from the moon, which acts upon them in the inverſe ratio of the ſquares of their diſtances. Thus the ſurface of this part of the ſea is firſt elevated; the ſurface of the adjacent parts is likewiſe elevated, but in a ſmaller degree; and the waters at the bottom of all theſe parts are raiſed by the ſame cauſe. Hence, as the whole portion of water under the moon is raiſed, the waters at a diſtance, upon which no attraction is exerted, muſt neceſſarily ruſh forward with precipitation to ſupply the place of thoſe which are elevated, or drawn towards the moon. It is in this manner that the flux, or high tide, is produced, which is more or leſs ſenſible on different coaſts, and which agitates the ſea not only at the ſurface, but at the greateſt depths. The reflux, or ebb, is a conſequence of the natural diſpoſition of the water, which, when no longer acted upon by the moon, ſubſides, and returns to occupy thoſe ſhores from which it had been forced to retire by a foreign power. The ſame effect is produced when the moon arrives at the antipode, or oppoſite meridian, but for a different reaſon: In the firſt caſe, the waters riſe, becauſe they are nearer the moon than any other part of the globe; and in the ſecond, they riſe, becauſe the moon is at the greateſt diſtance from them. It is eaſy to perceive that the effect muſt be the ſame; for, the waters here be-

ing leſs attracted than thoſe of the oppoſite hemiſphere, they will neceſſarily recede, and form an eminence, the higheſt point of which will be where the attraction is leaſt, that is, in the meridian oppoſite to the moon's ſtation, or to the place where ſhe was thirteen hours before. When the moon comes to the horizon, the tide is ebb, and the ſea is in its natural ſtate of equilibrium. But, when ſhe is in the oppoſite meridian, this equilibrium cannot exiſt; for the waters, at the place oppoſite to the moon, being then at their great diſtance from her, they are leſs attracted than the reſt of the globe; and hence their relative gravity, by which they are conſtantly kept in equilibrium, puſhes them towards the point oppoſite to the moon, in order to preſerve this equilibrium. Thus, in both caſes, when the moon is in the meridian of a place, or in the oppoſite meridian, the waters muſt be elevated nearly to the ſame height; and, conſequently, they muſt ebb or flow back when the moon is in the horizon, either at her riſing or ſetting. A motion, ſuch as we have deſcribed, neceſſarily agitates the whole maſs of the ocean, from its ſurface to its bottom; and, as the bottom is leſs affected by winds than the ſurface, the motion produced in the former, by the tides, is more regular and uniform.

From this alternate ebbing and flowing, there reſults, as already remarked, a conſtant motion of the ſea from eaſt to weſt; for the moon,

 which

which is the cauſe of the tides, moves from eaſt to weſt, and, by acting ſucceſſively in this direction, ſhe draws the waters after her. This motion is moſt perceptible in ſtraits. At the ſtraits of Magellan, for example, the tides riſe near 20 feet, and they continue at this height ſix hours; but the reflux, or ebbing, laſts only two hours, and the waters run to the weſt*. This inconteſtibly proves, that the reflux is not equal to the flux, and that, from both there reſults a motion to the weſt, which is ſtronger during the flux than the reflux. It is for this reaſon, that, in open ſeas, at great diſtances from land, the tides are only rendered perceptible by this general current of the waters from eaſt to weſt.

The tides are much higher between the tropics than in any other part of the ocean. They likewiſe riſe higher in places that ſtretch from eaſt to weſt, in long and narrow bays, and upon coaſts which are interrupted with iſlands and promontories. The higheſt known tides take place at one of the mouths of the Indus, where they riſe 30 feet perpendicular. They have alſo a remarkable elevation at Malaya, in the ſtraits of Sunda, in the Red Sea, in Nelſon's bay, at the mouth of the river St. Lawrence, upon the coaſts of China and Japan, at Panama, in the Gulf of Bengal, &c.

* See Narborough's Voyages.

The

The ſea's motiòn, from eaſt to weſt, is moſt obſervable in particular places. Voyagers have often remarked it in ſailing from India to Madagaſcar and Africa. It moves alſo with conſiderable force in the Pacific Ocean, and between the Moluccas and Brazil: But it is moſt violent in ſtraits: The waters are carried from eaſt to weſt, through the ſtraits of Magellan, for example, with ſuch rapidity, that their motion is perceptible, at a great diſtance, in the Atlantic ocean. It was this circumſtance, it is ſaid, that made Magellan conjecture that a ſtrait exiſted by which there was a communication with the two ſeas. In the ſtraits formed by the Manillas, in the channels between the Maldiva iſlands, and in the gulf of Mexico, between Cuba and Jucatan, there is a conſtant current from eaſt to weſt. This motion, in the gulf of Paria, is ſo violent, that its ſtrait is called the *Dragon's Mouth.* It is likewiſe violent in the ſea of Canada, in that of Tartary, and in Waigat's ſtraits, through which it forces enormous maſſes of ice into the northern ſeas. The Pacific ocean runs from eaſt to weſt through the ſtraits of Japan; the ſea of Japan runs towards China; and the Indian ocean runs weſtward through the ſtraits of Java, and other iſlands of India. It is, therefore, evident, that the ſea has a general and uniform motion from eaſt to weſt; and, it is certain, that the Atlantic runs towards America, and that the

Pacific ocean flies from it, as is apparent at Cape Current between Lima and Panama*.

In fine, the tides rise and fall alternately in six hours and a half upon most coasts, though they happen at different hours, according to the climate, and the position of particular lands. Thus the coasts of the sea are perpetually beat by the waves; and each tide carries off from the higher grounds small quantities of matter, and deposites them, at a distance, on the bottom of the ocean. In the same manner, each tide carries in, and deposites upon low coasts, sand, shells, and other sea-bodies, which gradually form horizontal strata, and give rise to downs, and little hills, similar to other hills, both in figure and internal structure. Thus the sea is constantly encroaching upon high coasts, and losing ground upon those that are low; and these effects are produced by the tides, and by violent winds.

To give an idea of the violent effects of a stormy sea against a high coast, I shall relate a fact attested by an eye-witness, a person worthy of the highest credit. In the largest of the Orkney islands, there are coasts composed of solid rock, above 200 feet high, and nearly perpendicular to the surface of the water. The tides, as is usual in islands and promontories, rise very high at this place. But, when a violent wind concurs with the flow of the tide, the agitation of the waters is so great, that they often rise

* See Varen. Geogr. p. 119.

above

above theſe rocks, and fall down in the form of rain: nay, to this amazing height, gravel, and ſtones as large as a man's fiſt, are raiſed from the foot of the rocks.

I myſelf ſaw, in the port of Leghorn, where the ſea is much more tranquil, a tempeſt in December 1731, which obliged the mariners to cut off the maſts of their veſſels, that were driven, by the violence of the wind, from their anchors in the road: the waters of the ſea ſurmounted fortifications of a great height; and as I was upon one of the moſt advanced works, before I could reach the town, I was more drenched with ſea-water than I could have been by the heavieſt rain.

Theſe examples may convey a notion of the violence with which the ſea acts againſt particular coaſts. This conſtant agitation gradually wears*, corrodes, excavates, and diminiſhes the quantity of the land. All theſe materials are tranſported and depoſited in places where the ſea is more tranquil. In the time of ſtorms, the water is foul and muddy, by the admixture of matters detached from the coaſts and from the bottom of the ſea. Theſe bodies, which are very vari-

* We are told by Shaw, in his travels, that, in many parts on the coaſt of Syria and Phœnicia, the rocks had been cut, by the ancients, into troughs of two or three yards long, and broad in proportion, for the purpoſe of making ſalt by evaporation. But, notwithſtanding the hardneſs of the rocks, theſe troughs are now almoſt totally obliterated by the agitation of the waves.

ous,

ous, and carried from great diſtances, are thrown upon the low ſhores, eſpecially after tempeſts, as ambergris on the weſt of Ireland, yellow amber upon the coaſts of Pomerania, cocoas upon the coaſts of India, &c. and ſometimes pumice, and other ſingular ſtones. On this occaſion, we may quote a paſſage from the New Voyages to the iſlands of America. 'When at St. Domingo,' ſays the author, 'I was preſented, among other 'things, with ſome light ſtones, brought in by 'the ſea in high ſouth winds: ſome of them 'were two and a half feet long, 18 inches broad, 'and about a foot thick; and yet they weighed 'not above five pounds. They were as white 'as ſnow, harder than pumice, of a fine grain, 'and appeared not to be porous. When, how'ever, they were thrown into water, they re'bounded like a foot-ball thrown againſt the 'ground. It was difficult to force them under 'water with the hand. I incloſed two of theſe 'ſtones with thin boards, and found that they 'bore 160 pounds without ſinking. They ſerved 'my negro for a ſhallop on which he divert'ed himſelf in ſailing about the quay*.' This ſtone muſt have been a pumice of a cloſe fine grain, which had been tranſported by the ſea from the neighbourhood of ſome volcano, in the ſame manner as ambergris, cocoas, common pumice, the ſeeds of plants, reeds, &c. are tranſported. It is chiefly on the coaſts of Ireland

* Tom. i. p. 260.

and

and of Scotland that obſervations of this kind have been made. The ſea, by its general motion from eaſt to weſt, ought to carry to America the productions of our coaſts; and it muſt be by the operation of ſome irregular movements, that the productions of the Eaſt and Weſt Indies, and of the northern regions, are brought upon our coaſts. The winds are probably the cauſe of theſe effects. In open ſeas, and at great diſtances from land, large portions of the water have been ſeen totally covered with pumice-ſtones. They could only come from volcanos in iſlands, or on the continent; and they have probably been tranſported to the open ſeas by currents. Before the ſouth part of America was diſcovered, and when it was not believed that the Indian ocean had any communication with ours, appearances of this kind firſt gave riſe to the ſuſpicion that ſuch a communication was not impoſſible.

The alternate motion of the tides, and the uniform motion of the ſea from eaſt to weſt, exhibit different appearances in different climates, according to the various indentations in the land, and the height of the coaſts. In ſome places the motion from eaſt to weſt is not perceptible; at others, it moves in a contrary direction, as on the coaſt of Guinea. But theſe contrary motions are occaſioned by the winds, by the poſition of the land, by the waters of great rivers, and by the diſpoſition of the bottom of the

the ſea. All theſe cauſes produce currents, which often change the direction of the general movement. But, as this motion from eaſt to weſt is the greateſt, moſt general, and conſtant, it ought to produce the moſt ſignal effects; and upon the whole, the ſea muſt gradually gain ground on the weſt, and loſe it on the eaſt; and although, upon coaſts where the weſt wind blows during the greateſt part of the year, as in France and Britain, the ſea may gain land on the eaſt, yet theſe exceptions deſtroy not the effect of the general cauſe.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XIII.

Of Inequalities in the Bottom of the Sea, and of Currents.

THE coafts of the fea may be divided into three kinds: 1. High coafts compofed of hard rocks, commonly perpendicular, and of a confiderable elevation, rifing fometimes to the height of 700 or 800 feet. 2. Low coafts, of which fome are almoft level with the furface of the water, and others have a fmall elevation, and are often bordered with rocks nearly of a level with the water, which give rife to breakers, and render the approach of fhips exceedingly dangerous. 3. Downs, or coafts formed by fand, either accumulated by the fea, or brought down and depofited by rivers: thefe downs

downs form hills of more or leſs elevation, according to circumſtances.

The coaſts of Italy are lined with marble and rocks of different ſpecies. Theſe rocks appear at a diſtance like perpendicular pillars of marble. The coaſts of France, from Breſt to Bourdeaux, conſiſt almoſt entirely of rocks on a level with the ſea, which occaſion breakers. The coaſts of England, of Spain, and of many other places, are bordered with rocks and hard ſtones, except particular ſpots which are employed as roads and harbours.

The depth of the water along the coaſt is generally proportioned to their elevation; a high coaſt indicates a deep water; and, on low coaſts, the water is commonly ſhallow. The inequalities at the bottom of the ſea near the coaſts likewiſe correſpond with the inequalities in the ſurface of the ground along the ſhore. This ſubject is illuſtrated in the following manner by a celebrated voyager.

'I have made it my general obſervation, that, 'where the land is fenced with ſteep rocks and 'cliffs againſt the ſea, there the ſea is very deep, 'and ſeldom affords anchor-ground; and, on 'the other ſide, where the land falls away with 'a declivity into the ſea, (although the land be 'extraordinary high within,) yet there are commonly good ſoundings, and conſequently an'choring; and, as the viſible declivity of the 'land appears near, or at the edge of the water, 'whether

'whether pretty ſteep, or more ſloping, ſo we 'commonly find our anchor-ground to be more 'or leſs deep or ſteep; therefore we come near-'er the ſhore, or anchor farther off, as we ſee 'convenient; for there is no coaſt in the world, 'that I know, or have heard of, where the land 'is of a continual height, without ſome ſmall 'valleys or declivities, which lie intermixed with 'the high land. They are the ſubſiding of val-'leys or low lands, that make dents in the ſhore 'and creeks, ſmall bays and harbours, or little 'coves, &c. which afford good anchoring, the 'ſurface of the earth being there lodged deep 'under water. Thus we find many good har-'bours on ſuch coaſts, where the land bounds 'the ſea with ſteep cliffs, by reaſon of the de-'clivities, or ſubſiding of the land between theſe 'cliffs: But, where the declenſion from the hills 'or cliffs is not within-land, between hill and 'hill, but, as on the coaſt of Chili and Peru, the 'declivity is toward the main ſea, or into it, the 'coaſt being perpendicular, or very ſteep from 'the neighbouring hills, as in thoſe countries 'from the Andes, that run along the ſhore, 'there is a deep ſea, and few or no harbours or 'creeks. All that coaſt is too ſteep for anchor-'ing, and hath the feweſt roads fit for ſhips 'of any coaſt I know. The coaſts of Gallicia, 'Portugal, Norway, and Newfoundland, &c. 'are coaſts like the Peruvian, and the high 'iſlands of the Archipelago; but yet not ſo

'scanty of good harbours; for, where there are 'short ridges of land, there are good bays at 'the extremities of those ridges, where they 'plunge into the sea; as on the coast of Ca- 'raccos, &c. The island of Juan Fernandez, 'and the island of St. Helena, &c. are such high 'land with deep shore: And, in general, the 'plunging of any land under water, seems to 'be in proportion to the rising of its continuous 'part above water, more or less steep; and it 'must be a bottom almost level, or very gently 'declining, that affords good anchoring, ships 'being soon driven from their moorings on a 'steep bank; therefore, we never strive to an- 'chor where we see the land high, and bounding 'the sea with steep cliffs; and, for this reason, 'when we came in sight of States-Island, near 'Terra del Fuego, before we entered into the 'South-Seas, we did not so much as think of an- 'choring after we saw what land it was, because 'of the steep cliffs which appeared against the 'sea; yet there might be little harbours or coves 'for shallops, or the like, to anchor in, which 'we did not see, or search for.

'As high steep cliffs bounding on the sea 'have this ill consequence, that they seldom af- 'ford anchoring; so they have this benefit, that 'we can see them far off, and sail close to them, 'without danger; for which reason we call 'them bold shores; whereas low land, on the 'contrary, is seen but a little way, and in many

'places

'places we dare not come near it, for fear of 'running a-ground before we see it. Besides, 'there are, in many places, shoals thrown out 'by the course of great rivers, that from the 'low land fall into the sea.

'This which I have said, that there is usually 'good anchoring near low lands, may be illus-'trated by several instances. Thus, on the 'south side of the bay of Campeachy, there is 'mostly low land, and there also is good an-'choring all along shore; and, in some places 'to the eastward of the town of Campeachy, 'we shall have so many fathom as we are leagues 'off from land; that is, from 9 or 10 leagues 'distance, till you come within 4 leagues; and 'from thence to land it grows but shallower. 'The bay of Honduras also is low land, and con-'tinues mostly so, as we passed along from thence 'to the coasts of Portobel, and Cartagena, till 'we came as high as Santa Martha; afterwards 'the land is low again, till you come towards 'the coast of Caraccos, which is a high coast 'and bold shore. The land about Surinam, on 'the same coast, is low and good anchoring, and 'that over on the coast of Guiney is such also. 'And such, too, is the bay of Panama, where 'the pilot-book orders the pilot always to sound, 'and not to come within such a deep, be it by 'night or day. In the same seas, from the high 'land of Gautimala in Mexico, to California, 'there is mostly low land and good anchoring.

'In the main of Aſia, the coaſt of China, the 'bay of Siam and Bengal, and all the coaſt of 'Coromandel, and the coaſt about Malacca, and 'againſt it the iſland of Sumatra, on that ſide, 'are moſtly low anchoring ſhores. But, on the 'weſt ſide of Sumatra, the ſhore is high and 'bold; ſo moſt of the iſlands lying to the 'eaſtward of Sumatra; as the iſlands Borneo, 'Celebes, Gilolo, and abundance of iſlands of 'leſs note, lying ſcattered up and down thoſe 'ſeas, are low land, and have good anchoring 'about them; with many ſhoals ſcattered to and 'fro among them; but the iſlands lying againſt 'the Eaſt-Indian Ocean, eſpecially the weſt ſides 'of them, are high land and ſteep, particularly 'the weſt parts, not only of Sumatra, but alſo 'of Java, Timor, &c. Particulars are endleſs; 'but, in general, 'tis ſeldom but high ſhores and 'deep waters, and, on the other ſide, low land 'and ſhallow ſeas are found together*.'

It is, therefore, fully eſtabliſhed by the obſervations of navigators, that there are in the bottom of the ſea, conſiderable mountains, and other inequalities. We are alſo aſſured by the teſtimony of divers, that there are ſmaller inequalities occaſioned by rocks, and that the cold is greateſt in the hollows or valleys. In general, as formerly remarked, the depths of open ſeas augment in proportion to their diſtance from the coaſts. It appears, from M. Buache's chart of that part of the ocean which lies be-

* Dampier's Voyages, vol. i. p. 422, 423, 424, 425.

tween

tween the coaſts of Africa and America, and from the draughts he has given us of the ſea from Cape Tagrin to Rio-grand, that the bottom of the ocean is as irregular as the ſurface of the land; that abrolhos, where there are *vigies*, and where ſome of the rocks are on a level with the water, are only the tops of large and high mountains, of which Dolphin iſland is one of the moſt elevated points; that the Cape de Verd iſlands are likewiſe the tops of mountains; and that all round theſe abrolhos and iſlands, the depth of the ſea is unfathomable.

With regard to the qualities of the different ſoils at the bottom of the ſea, little can be ſaid with preciſion, as all our knowledge is derived from ſounding and from divers. We only know, that ſome places are covered with ſlime and mud of a conſiderable thickneſs, in which anchors can have no hold: It is probable that, in theſe places, the mud is depoſited by rivers. Other parts are covered with ſand of different kinds, ſimilar to thoſe upon land. In others are heaps of ſhells, madrepores, corals, and other productions of inſects, juſt beginning to unite and to aſſume the form of ſtones: In others, we find fragments of ſtones, gravel, and frequently ſtones and marbles completely formed. In the Maldiva iſlands, for example, they build their houſes with a hard ſtone raiſed from ſome fathoms under water. At Marſeilles very good marble is raiſed from the bottom of the

 ſea,

ſea, which, inſtead of waſting or deſtroying ſtones and marble, creates and preſerves them: It is the ſun, the earth, the air, and the rains, which alone corrupt and deſtroy theſe ſubſtances.

The bottom of the ſea muſt be compoſed of the ſame materials as the ſurface of the earth, ſince the very ſame ſubſtances are found on both. At the bottom of ſome parts of the ocean are vaſt collections of ſhells, madrepores, and corals; and we find, upon land, numberleſs quarries, banks of chalk, and of other ſubſtances, mixed with the ſame ſhells, madrepores, and corals; ſo that, in every view, the dry parts of this globe reſemble thoſe covered with the waters, both in compoſition of materials, and in ſuperficial inequalities.

To theſe inequalities at the bottom, we muſt aſcribe the origin of currents; for, if the bottom were uniform and level, there could be no current but the general motion from eaſt to weſt, and ſuch as might occaſionally be produced by the winds. But what inconteſtibly proves, that moſt currents are produced by the tides, and take their direction from inequalities at the bottom, is, that they uniformly follow the tides, and change their courſe at every ebb and flow*. This fact is confirmed by the teſtimony

* See Pietro della Valle on the currents in the Gulf of Cambaia, Vol. vi. p. 363.

of

of all navigators, who unanimoufly affirm, that, in thofe places where the tides are moft impetuous, the currents are likewife moft rapid.

Thus it is apparent, that the tides give rife to currents, and that they always follow the direction of the oppofite hills or mountains between which they run. Currents produced by winds likewife obferve the direction of the eminences concealed under the waters; for they feldom run in the direct path of the winds; neither do thofe produced by the tides invariably obferve the courfe pointed out by their original caufe.

To give a diftinct idea of the origin of currents, let it be remarked, that they take place in all feas; that fome are rapid, and others flow; that fome are of great extent both in length and breadth, and others fhorter and narrower; that the fame caufe by which they are produced, whether it be the winds or the tides, frequently beftows on each a difference both in celerity and direction; that a north wind, for example, which ought to produce a general motion towards the fouth, gives rife, on the contrary, to a number of feparate currents, very different, both in their direction and extent, fome running fouth, others fouth-eaft, and others fouth-weft; fome are rapid, others flow; fome long and broad, and others fhort and narrow: In a word, their motions are fo various and combined, that they lofe all refemblance to their

general cauſe. When a contrary wind blows, every motion is uniformly reverſed; and the courſe of the different currents is preciſely the ſame as would neceſſarily take place between two oppoſite and neighbouring hills upon the ſurface of the land, were it covered with water. Of this, the Maldiva and Indian iſlands, where the winds blow and the currents run regularly for ſix months in oppoſite directions, afford moſt ſtriking examples. The ſame thing has been remarked of currents between ſhoals and ſand-banks. In general, all currents, from whatever cauſe they proceed, have the ſame dimenſions, and the ſame direction through their whole courſe; but they differ greatly from each other in every reſpect. This uniformity and variety can proceed from no other cauſe but the inequalities of the hills, mountains, and valleys, at the bottom of the ocean; for, it is an eſtabliſhed fact, that the current between two iſlands follows the direction of the coaſts; and the ſame phænomenon is exhibited between ſhoals and ſand-banks. The hills and mountains in the ſea, therefore, may be conſidered as the banks which contain and direct the currents: Hence a current is a river, the breadth of which is determined by that of the valley through which it runs; its rapidity is proportioned to the force by which it is produced, combined with the breadth of the interval through which it paſſes; and its direction is marked out by the poſition

poſition of the hills and other inequalities between which it ſhapes its courſe.

An opportunity is now afforded us of explaining that ſingular correſpondence between the angles of hills and mountains, which is obſervable in every country of the world. We have already remarked this uniform correſpondence of angles in the banks of rivers. The cauſe of this effect depends on the laws of hydroſtatics, and might be eaſily explained. But it is ſufficient for our preſent purpoſe, that the fact is general, and univerſally known; and every man may ſatisfy himſelf with his own eyes, that, when the bank of a river projects into the land, to the left, for inſtance, the oppoſite bank, on the contrary, makes a projection from the land on the right.

The currents of the ocean, therefore, which ought to be regarded as large rivers, and as ſubject to the ſame laws as thoſe on land, muſt, like them, have formed, through the whole extent of their courſe, many ſinuoſities or windings with correſponding angles or projections: And, as the banks of currents are hills and mountains, either above or below the ſurface of the water, they muſt have produced on theſe eminences the ſame effects as our rivers do upon their banks. Thus, we have no longer any reaſon to be aſtoniſhed, that our hills and mountains, which were formerly covered with the ſea, and formed by the ſediments of its waters,

ters, ſhould have aſſumed, by the motion of its currents, this regular figure, ariſing from the correſpondence of their oppoſite angles. They were originally banks of currents, or of ſea-rivers, and muſt neceſſarily have aſſumed a figure and direction ſimilar to thoſe of land-rivers.

This alone, independent of the other proofs which we have adduced, is ſufficient to ſhow, that all our preſent continents and iſlands were formerly covered with the waters of the ocean, and throws much light on the theory which I have been endeavouring to eſtabliſh. It was not enough to have proved that the internal ſtrata of the earth were formed by ſediments of the waters; that the mountains were elevated by ſucceſſive accumulations of theſe ſediments; or, that many ſtrata were impregnated with ſhells and other productions of the ſea. It was ſtill neceſſary to inveſtigate and aſſign the real cauſe of the correſpondence in the angles of mountains, which hitherto had never been attempted, but which, when united with the other proofs, forms a connected chain of evidence in ſupport of my theory, as complete as the nature of phyſical reaſoning will admit.

The moſt conſpicuous currents of the ocean are thoſe in the Atlantic near the coaſt of Guiney. They extend from Cape Verd to the bay of Fernandpo. They run from weſt to eaſt, which

which is contrary to the general motion of the sea; and they are so rapid, that vessels sail in two days from Moura to Rio de Benin, about 150 leagues, but require six or seven weeks to return. It would be impossible to clear these latitudes, were it not by means of the tempestuous winds which suddenly arise in them: But there are sometimes whole seasons in which the mariner is obliged to remain stationary, on account of perpetual calms, the sea having here no motion but what it derives from the currents; and these always run in upon the coasts, from which they extend not above 20 leagues. Near the island of Sumatra, there are rapid currents, which run from south to north, and which have probably given rise to the bay, between Malacca and India. We find similar currents between Java and the lands of Magellan, and between the Cape of Good Hope and Madagascar, especially on the African coast from Natal to the Cape. In the Pacific Ocean, upon the coasts of Peru, and the rest of America, the waters move from south to north, which is probably owing to the constant blowing of the south wind. The same motion from south to north has been remarked on the coasts of Brasil, from Cape St. Augustine to the Antilles, and from the mouth of the Manilla Straits to the Philippines and Japan*.

* See Varen. Geogr. p. 140.

There

There are violent currents in the neighbourhood of the Maldiva iſlands; and between theſe iſlands, as already obſerved, the currents run alternately in oppoſite directions ſix months in the year, and are probably occaſioned by the trade-winds.

We here enumerate ſuch currents only as are remarkable both for their extent and their rapidity; becauſe the number of leſſer currents is almoſt infinite. The tides, the winds, and every cauſe that agitates the waters, produce currents, which are more or leſs perceptible in different places. We have already remarked, that the bottom of the ſea is, like the land, interſected with mountains and valleys, ſhoals and ſand-banks. In all the mountainous places, the currents muſt neceſſarily be violent; and, where the bottom is ſmooth and level, they are almoſt imperceptible; for the rapidity of a current muſt augment in proportion to the obſtacles with which the waters have to encounter. The current between two chains of mountains will be more or leſs violent in proportion to their diſtance. The ſame thing muſt happen between two banks of ſand, or two adjacent iſlands. It is, accordingly, remarkable, that in the Indian ocean, which is interſected with an innumerable quantity of iſlands and ſand-banks, there are every where currents, which, by their rapidity, render navigation extremely dangerous.

Currents are not only occafioned by inequalities at the bottom, but a fimilar effect is produced by the coafts, from which the waters are repelled to greater or lefs diftances. This regorging of the waters may be rendered perpetual and violent by particular circumftances: An oblique pofition, for example, of a coaft, its contiguity to a bay or a great river, a promontory, or any particular obftacle to the general movement of the waters, will always give rife to a current: Now, as nothing is more irregular than the bottom and the coafts of the fea, the number of currents which every where appear ought not to create furprife.

All currents have a determinate breadth, proportioned to the interval between the two eminences which limit them. They run in the fame manner as land-rivers; they form a channel, and cut their banks in a regular manner, with correfponding angles: In fine, the currents of the ocean have fcooped out our valleys, fhaped our mountains, and beftowed upon the land, while it remained under the furface of the waters, the form in which it now appears.

If any doubt fhould remain concerning the correfpondence in the angles of mountains, I appeal to the teftimony of every man's obfervation. Every traveller may remark this correfpondence in oppofite hills. When a hill makes a projection to the right, the oppofite one uniformly recedes to the left. Befides, in oppofite

hills

hills separated by valleys, there is rarely any difference in their height. The more I observe the contours and elevations of hills, I am the more convinced of the correspondence of their angles, and of their resemblance to the channels and banks of rivers. It was the repeated observation of this surprising regularity and resemblance that first suggested the idea of the theory of the earth which I am now supporting. When to this are added the parallelism of the strata, and the shells so universally incorporated with different materials, no subject of this nature can admit of a greater degree of probability.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XIV.

Of Regular Winds.

IN our climates, nothing can appear to be more capricious and irregular than the force and direction of the winds. But there are ſome countries where this irregularity is not ſo great, and others where the wind blows conſtantly in the ſame direction, and with nearly the ſame degree of force.

Though the motions of the air depend on many cauſes; yet there are ſome more conſtant and powerful than others. But it is difficult to eſtimate their preciſe effects, becauſe theſe are often modified by ſecondary cauſes.

The heat of the ſun is the moſt powerful cauſe of winds: It produces a conſiderable and ſucceſſive

succeffive rarefaction in the different parts of the atmofphere, and gives rife to an eaft-wind, which blows conftantly between the Tropics, where the rarefaction is greateft.

The force of the fun's attraction upon the atmofphere, and even that of the moon, are inconfiderable, when compared with the caufe juft mentioned. This force, it is true, produces a motion in the air fimilar to that of the tides in the fea: But, though the air is elaftic, and 800 times lighter than water, the motion produced by attraction cannot exceed what is excited in the waters of the ocean by the fame caufe; for the action of gravity being proportioned to the quantity of matter, it muft elevate a fea of water, of air, or of quickfilver, nearly to the fame height. Hence the influence of the planets upon the air muft be inconfiderable*; and, though it muft occafion a flight motion from eaft to weft, this motion becomes altogether infenfible when compared with that produced by the heat of the fun: But as the rarefaction is always greateft when the fun is in the zenith, the current of air muft follow the courfe of the fun, and produce a conftant wind from eaft to weft. At fea, this wind blows perpetually in the Torrid Zone, and at land, in moft

* See Reflections fur la Caufe Generale des Vents, par M. D'Alembert.

places

places between the Tropics. It is this wind which we perceive when the ſun riſes; and, in general, eaſt winds are more frequent, and more violent, than weſt winds. The general wind, from eaſt to weſt, extends even beyond the Tropics. It blows ſo conſtantly in the Pacific ocean, that the ſhips coming from Acapulco to the Philippines, perform their voyage, which is more than 2700 leagues, without the leaſt danger, and almoſt without the neceſſity of being directed. In the Atlantic, between Africa and Braſil, this wind is equally conſtant. It is likewiſe felt between the Philippines and Africa; but there it is leſs conſtant, on account of the obſtacles it meets with from the numerous iſlands in that ſea; for it blows, during the months of January, February, March and April, between the Mozambique coaſt and India; but it gives place to other winds during the reſt of the year: And, though it is leſs perceptible on the coaſts than on the open ſea, and ſtill leſs in the interior parts of continents than on the coaſts, yet, in ſome places, it blows almoſt perpetually, as on the eaſt coaſts of Braſil, of Loango in Africa, &c.

This wind is conſtant under the Line; and, therefore, in going from Europe to America, mariners direct their courſe ſouthward, along the coaſts of Spain and Africa, till they come within 20 degrees of the Equator, where they fall in with the eaſt, or trade-wind, which car-

ries them directly to the coaſt of America. By means of the ſame wind, the voyage from Acapulco to the Philippines is performed in two months; but the return from the Philippines to Acapulco is much more difficult, and requires a longer time. About 28 or 30 degrees on this ſide of the Line, the weſt wind is equally conſtant; and, for this reaſon, the veſſels returning from the Weſt Indies to Europe, obſerve not the ſame route as in going out. Thoſe from New Spain run north along the coaſt till they arrive at the Havannah, in the iſland of Cuba; and from thence they proceed northward till they fall in with the weſt wind, which carries them to the Azores, and then to Spain. In the ſame manner, veſſels returning by the South Sea from the Philippines or China, to Peru or Mexico, ſail north as far as Japan; and, under that latitude, they proceed till they arrive at a certain diſtance from California; and from thence, following the coaſt of New Spain, they reach Acapulco. Theſe eaſt winds blow not always from the ſame point; but, in general, they blow from the ſouth-eaſt, from April to September, and from the north-eaſt from November to April.

The eaſt wind, by its conſtant action, augments the general motion of the ſea from eaſt to weſt. It alſo produces perpetual currents, ſome of them running from eaſt to weſt, and others from eaſt to ſouth eaſt, or north-weſt, according to the direction of the eminences, or

chains

chains of mountains, below the ſurface: The valleys or intervals between them ſerve as channels to theſe ſea-rivers. The variable winds which blow ſometimes from the eaſt, and ſometimes from the ſouth, likewiſe produce currents, which change their direction with that of the wind.

The winds that blow conſtantly for ſome months are commonly ſucceeded by contrary winds, which oblige the mariner to wait for that which is moſt favourable to his deſtination. When theſe winds change, they often produce, for ſeveral days, and ſometimes for a month, or even two months, a perfect calm, or dreadful tempeſts.

Theſe general winds, occaſioned by the rarefaction of the atmoſphere, are variouſly combined and modified by different cauſes, and in different climates. In that part of the Atlantic which lies under the Temperate Zone, the north wind blows almoſt conſtantly during the months of October, November, December, and January. Theſe months, therefore, are moſt favourable for ſhips going to the Indies, which are carried over the Line by this wind: And it is a well known fact, that veſſels which depart from Europe in March, frequently arrive not ſooner at Braſil than thoſe which ſet out in the following October. The north wind reigns almoſt perpetually, during the winter, off Nova Zembla, and other northern coaſts. At Cape de Verd, the

ſouth wind blows, during the month of July, which is the rainy ſeaſon, or winter, in that climate. At the Cape of Good Hope, the north-weſt wind blows during the month of September: The ſame wind blows at Patna in the Eaſt Indies, during the months of November, December, and January, and occaſions great rains; but the eaſt wind prevails during the other nine months. In the Indian Ocean, between Africa and India, and as far as the Molucca iſlands, the trade-wind from eaſt to weſt reigns from January to the beginning of June; the weſt winds begin in Auguſt or September; and, in the interval between June and July, there are dreadful tempeſts, generally from the north winds; but theſe winds are more variable on the coaſts than in the open ſeas.

In the kingdom of Guzarat, and upon the neighbouring coaſts, the north winds blow from March to September; and, during the other months, the ſouth winds almoſt always prevail. The Dutch, in returning from Java, ſet out in January or February, by the aſſiſtance of the eaſt wind, which is felt as far as the 18th degree of ſouth latitude; and then they meet with ſouth winds, which carry them to St. Helena*.

Some regular winds are produced by the melting of the ſnows. This was remarked by the ancient Greeks. During ſummer, a north-eaſt wind, and a ſouth-eaſt one during winter,

* See Varen. Geogr. cap. 20.

was

was obſerved to take place in Thracia, in Macedonia, in the Egean Sea, and even in Egypt and Africa; and winds of the ſame kind have been remarked in Congo, at Guzarat, and at the extremity of Africa, which are all occaſioned by the melting of the ſnows. Regular winds, which laſt but a few hours, are alſo produced by the motion of the tides; and, in many places, as on the coaſts of New Spain, of Congo, of Cuba, &c. a wind blows from the land during the night, and from the ſea during the day.

The north winds are equally regular within the polar circles; but they become more and more imperceptible as we approach the Equator: This remark is applicable to both poles.

In the Atlantic and Ethiopic ocean, within the tropics, an eaſt wind blows during the whole year, without any conſiderable variation, except in ſome ſmall ſpots, where it changes according to the ſituation of coaſts, and other circumſtances: 1*ſt*, Near the coaſt of Africa, and about the 28th degree of north latitude, veſſels are certain of finding a freſh gale from the north-eaſt, or north-north-eaſt, which accompanies them to the 10th degree of the ſame latitude, about 100 leagues from the coaſt of Guinea; and at the 4th degree of north latitude, they meet with calms and tornado's. 2*d*, In going by the Caribbee iſlands, this wind turns more and more eaſterly, in proportion as veſſels approach the American coaſt. 3*d*, The

limits of theſe variable winds, in the Atlantic, are more extenſive upon the coaſts of America than upon thoſe of Africa. Along the coaſt of Guinea, from Sierra Leona to the iſland of St. Thomas, an extent of about 500 leagues, there is a perpetual ſouth, or ſouth-weſt wind. The narroweſt part of the Atlantic is from the coaſt of Guinea to Braſil, where it is not above 500 leagues over. Veſſels, however, that depart from Guinea, are obliged to ſhape their courſe ſouthward, eſpecially when they ſet out in the months of July or Auguſt, in order to fall in with the ſouth-eaſt winds, which blow conſtantly during this ſeaſon*.

In the Mediterranean, the eaſt wind blows from the land in the evening, and the weſt wind from the ſea in the morning. The ſouth wind, which is accompanied with rain, and blows commonly during the latter end of autumn, at Paris, in Burgundy, and Champagne, yields to a mild north-eaſt wind, which produces that fine weather vulgarly called Saint Martin's Summer†.

Doctor Liſter alledges, that the eaſt wind, which reigns during the whole year between the tropics is occaſioned by the tranſpiration of the plant called the *ſea-lentil*, which abounds in theſe climates; and that the difference of land-winds is owing to the different ſituation of trees

* See Phil. Tranſ. Abridg. vol. ii. p. 129.

† See Traité de eaux de M. Mariotte.

and

and forefts. This ridiculous whim he affigns as the caufe of the winds; and, in his opinion, the wind is ftrongeft at mid-day, becaufe the tranfpiration from plants is then greateft; and the wind, continues he, blows from eaft to weft, becaufe all plants are, in fome meafure, fun-flowers, and tranfpire moft from the fide oppofed to the fun *.

Other authors have affigned the diurnal motion of the earth as the caufe of this eaft wind. This notion is fpecious: But every man, who has the leaft knowledge of phyfics, muft allow, that no fluid which furrounds the earth can be affected by its rotation; that the air muft move along with the earth itfelf; and that the rotatory motion is equally imperceptible in the atmofphere as on the furface of the earth.

The principal caufe of the winds, as already remarked, is the heat of the fun †; for, whatever rarifies or condenfes the air, muft produce a wind, or current, in a direction oppofite to thofe places where the rarefaction or condenfation is greateft.

The preffure of clouds, exhalations from the earth, the explofion of meteors, rains, &c. likewife produce confiderable agitations in the atmofphere. Each of thefe caufes, when varioufly combined, produce different effects. As it is in vain to attempt a complete theory of the winds, I confine myfelf to their hiftory.

* See Phil. Tranf. No. 156.

† See Halley's Treatife on this fubject in the Phil. Tranf.

If we had a ſeries of obſervations upon the direction, the force, and the variations of the winds in the different climates of the earth, and if theſe obſervations were ſufficiently numerous and exact, we might be enabled to form more complete ideas with regard to the cauſes of the different changes in the atmoſphere.

The winds are more regular at ſea than upon land; becauſe their motion is not interrupted. But, upon land, the direction is frequently changed by the interpoſition of mountains, foreſts, cities, and other obſtacles. Winds are often reflected from mountains with a force nearly equal to that of their original current: Theſe winds are exceedingly irregular, becauſe their direction depends on the contour, the height, and the ſituation of the mountains from which they rebound. The ſea-winds alſo blow with more force and uniformity, and laſt longer: The land-winds, however violent, have intermiſſions, and moments of repoſe: But, at ſea, the current of the air, having no obſtacles to contend with, is uniform and perpetual.

At ſea, the eaſt winds, and thoſe which come from the Poles, are generally ſtronger than the weſt winds, and thoſe that proceed from the Equator. But, at land, the ſouth and weſt winds are more or leſs violent, according to the different ſituation of particular countries. During ſpring and autumn, the winds, both at ſea and land, are more violent than in ſummer or winter,

ter. For this fact, ſeveral reaſons may be aſſigned: 1. In ſpring and autumn the tides are higheſt; and, conſequently, the winds they excite are moſt violent during theſe ſeaſons: 2. The motion produced in the atmoſphere by the action of the ſun and moon, or the tides of the air, muſt likewiſe be greateſt about the equinoxes: 3. The melting of the ſnows in ſpring, and the condenſation of the vapours exhaled in ſummer by the ſun, and which fall down in the autumn in the form of rain, produce, or, at leaſt, augment the force of the winds: 4. The tranſition from heat to cold, or from cold to heat, muſt create conſiderable augmentation and diminution in the volume of the air, which alone is ſufficient to raiſe great winds.

Contrary currents in the atmoſphere have often been remarked. We ſee ſome clouds moving in one direction, and others, either above or below them, proceeding in a direction perfectly oppoſite. This contrariety of motion never continues long; becauſe its general cauſe is the reſiſtance of ſome large cloud, which reflects the wind in a direction oppoſite to its natural courſe, but is ſoon diſſipated.

The winds are more violent in proportion to the elevation of the ground, till it arrive at the ordinary ſtation of the clouds, which is about one-fourth or one-third of a league perpendicular height; and, beyond this, the ſky is generally ſerene, eſpecially in ſummer, and the wind

gradually

gradually diminiſhes: It is even ſaid to be altogether imperceptible on the tops of the higheſt mountains. However, as the ſummits of theſe mountains are covered with ice and ſnow, it is natural to think that this region of the air is agitated during the fall of the ſnows, and that the winds are imperceptible in the ſummer ſeaſon only. The light vapours which are raiſed in ſummer fall in the form of dews; but, in winter, they are condenſed, and fall on the tops of the mountains in the form of ſnow or ice, which may raiſe conſiderable winds at that altitude.

The celerity of a current of air is augmented when its paſſage is contracted. The ſame wind, which is but ſlightly felt in a large open plain, becomes violent in its progreſs through a narrow paſs in a mountain, or between two high houſes; and it is moſt violent at the tops of the buildings or of the mountain, becauſe the air, being compreſſed by theſe obſtacles, is augmented both in volume and denſity; and, as its celerity remains the ſame, its force or momentum muſt be increaſed. It is for this reaſon that the wind appears to be more violent near a church or a tower than at a diſtance from them. I have often remarked, that the wind reflected from a building ſtanding by itſelf, is ſtronger than the direct wind by which it was produced. This effect can be owing to no other cauſe than the compreſſion of the air againſt the building from which it rebounds.

As

As the denſity of the air is greateſt at the ſurface of the earth, it is natural to conclude, that the wind muſt there alſo be moſt violent; and this concluſion is, I apprehend, juſt, when the ſky is ſerene: But, when it is charged with clouds, the action of the wind will be moſt violent at the height of the clouds, which are denſer than air, as they fall in the form of rain or of hail. In computing the force of wind, therefore, we ought to eſtimate not only its velocity, but likewiſe the denſity of the air; for two winds, of equal velocities, may differ greatly in their force, if the denſities of the air be unequal. From this remark, we may learn the imperfection of thoſe machines which have been employed for meaſuring the velocity of the winds.

Particular winds, whether they be direct or reflected, are more violent than thoſe which are general. The interrupted action of land-winds depends on the compreſſion of the air, which renders every blaſt more violent than if the current were uniform. A uniformly continued ſtream of air produces not ſuch havock as the fury of thoſe winds which blow, as it were, by paroxyſms. But of this we ſhall treat more fully in the next article.

The winds, in their various directions, may be conſidered under general points of view, from which, perhaps, ſome uſeful deductions may be drawn. For example, the winds may be divided into Zones. The eaſt wind, which extends

extends 25 or 30 degrees on each ſide of the Equator, exerts its force round the globe within the Torrid Zone. The north wind blows with equal conſtancy in both the Frigid Zones. Thus, the eaſt wind occupies the Torrid Zone, and the north wind the Frigid Zones. With regard to the Temperate Zones, the winds peculiar to them may be conſidered only as currents of air, produced by the combination of the two principal winds, which give riſe to all thoſe that come from the eaſtern points; and the weſt winds, which are common in the Temperate Zones, both in the Pacific and Atlantic Oceans, may be conſidered as reflections from the continents of Aſia and America, but deriving their origin principally from the eaſt and north winds.

Though we have ſaid, that, generally ſpeaking, the eaſt wind blows round the globe 25 or 30 degrees on each ſide the Equator; yet it muſt be acknowledged that, in ſome places, it extends not ſo far, and that its direction is not throughout from eaſt to weſt; for, on this ſide of the Equator, it is eaſt-north-eaſt, and, beyond the Equator, it is eaſt-ſouth-eaſt; and, the more we recede from the Equator, its direction is the more oblique. The Equator is the line under which the direction of the wind from eaſt to weſt is moſt exact. In the Indian Ocean, for example, the general wind from eaſt to weſt extends not above 15 degrees beyond the Equator. In going from Goa to the Cape of Good Hope, this

this wind is not felt beyond the 12th degree of ſouth latitude, nor is it perceptible on this ſide of the Equator. But, after arriving at the 12th degree of ſouth latitude, this wind continues to the 28th degree. In the ſea which ſeparates Africa from America, there is an interval from the 4th degree of north latitude to the 10th or 11th of ſouth latitude, where this general wind is not perceived. But, beyond the 10th or 11th degree, it extends to the 30th.

There are likewiſe many deviations in the trade-winds, which have an alternate motion. Some continue for a longer or ſhorter time; others have a greater or leſſer extent; others are more or leſs regular, and more or leſs violent. The following, according to Varenius, are the principal phænomena of theſe winds: ‘ In the ‘ ocean between Africa and India, and as far as ‘ the Molucca iſlands, the eaſt wind commences ‘ in January, and continues to the beginning of ‘ June. In the month of Auguſt, the weſt wind ‘ begins, and continues for three or four months. ‘ In the interval between theſe trade-winds, ‘ which is from the end of June to the beginning of Auguſt, the ſea is infeſted with violent ‘ tempeſts from the north.

‘ Theſe winds are ſubject to the greateſt va- ‘ riations near the coaſts: Veſſels cannot take ‘ their departure from the coaſt of Malabar, and ‘ other ports on the weſt coaſt of the peninſula ‘ of India, to Africa, Arabia, or Perſia, but from

'the month of January to April or May; for, 'at the end of May, and during the months of 'June, July, and Auguſt, the tempeſts from 'the north and north-eaſt are ſo violent, that 'no ſhips can keep the ſeas. But, on the 'other ſide of this peninſula, in the ſea which 'waſhes the coaſt of Coromandel, there are no 'tempeſts of this kind.

'Veſſels depart from Java, Ceylon, and ſe-'veral other places, for the Molucca's in Sep-'tember, becauſe the weſt wind begins then to 'blow in theſe regions. However, when 15 'degrees ſouth of the Equator, this wind ceaſes, 'and they fall in with the trade-wind, which, 'in this place, blows from the ſouth-eaſt. In 'the ſame manner, veſſels depart from Cochin 'for Malacca in March; becauſe, at this time, 'the weſt wind begins to blow. Thus the weſt 'winds ariſe at different times, in different parts 'of the Indian Ocean. The times of departure 'are different from Java to the Molucca's, from 'Cochin to Malacca, from Malacca to China, 'and from China to Japan.

'At Banda, the weſt winds terminate at the 'end of March; calm and variable winds occu-'py the month of April; and the eaſt winds 'begin with great violence in May. At Cey-'lon, the weſt winds commence about the 'middle of March, and continue to the beginning 'of October, when the eaſt, or rather eaſt-north-'eaſt winds, return. At Madagaſcar, they have

'north

north or north-weſt winds from the middle
‘ of April to the end of May; but eaſt and
‘ ſouth winds in February and March. From
‘ Madagaſcar to the Cape of Good Hope, the
‘ northerly winds prevail during the months of
‘ March and April. In the gulf of Bengal, af-
‘ ter the 20th of April, the ſouth winds blow
‘ with violence; and, before this period, the
‘ ſouth-weſt and north-weſt winds prevail. The
‘ weſterly winds are alſo violent in the Chineſe
‘ ſea during the months of June and July. This
‘ is, therefore, the moſt proper ſeaſon for ſail-
‘ ing from China to Japan: But, in returning
‘ from Japan to China, February and March are
‘ preferable, becauſe the eaſterly winds then
‘ prevail.

‘ There are ſome winds which may be con-
‘ ſidered as peculiar to certain coaſts: For ex-
‘ ample, a ſouth wind blows almoſt perpetually
‘ on the coaſts of Chili and Peru. It begins
‘ about the 46th degree of ſouth latitude, and ex-
‘ tends beyond Panama, which makes the voy-
‘ age from Lima to Panama more eaſy and ex-
‘ peditious than the return. The weſterly winds
‘ blow almoſt continually on the coaſts of Ma-
‘ gellan's land, in the neighbourhood of the
‘ ſtraits of La Maire. Upon the Malabar coaſt,
‘ they have almoſt conſtantly north and north-
‘ weſt winds. The north wind is very frequent
‘ on the coaſt of Guinea. The weſterly winds
‘ reign

'reign upon the coaſts of Japan during the 'months of November and December.'

The periodic, or alternate winds, mentioned above, are peculiar to the ſea. But, upon land there are alſo periodic winds, which return at certain ſeaſons or particular days, or even at ſtated hours. On the coaſt of Malabar, for example, an eaſterly land-wind blows from September to April: It generally commences at midnight, and ends at noon; and it is not perceptible at 12 or 15 leagues from the coaſt. From noon to midnight, there is a gentle weſterly breeze from the ſea. Upon the coaſts of New Spain in America, and upon thoſe of Congo in Africa, land-winds blow during the night, and ſea-winds during the day. Winds blow from all the coaſts of Jamaica during the night, which prevents the landing, or ſailing of ſhips, with ſafety, before the riſing of the ſun.

In winter, the port of Cochin is inacceſſible; neither can any veſſel get out; becauſe the winds are ſo impetuous, that no veſſels can keep the ſea; and, beſides, the weſt wind, which blows with great fury, drives ſuch a quantity of ſand into the mouth of the river, as renders it impoſſible for ſhips of any burthen to enter it for ſix months of the year. But the eaſt wind, which blows during the other ſix months, drives back the ſand into the ſea, and opens the mouth of the river. At the ſtraits of Babelmandel, there is a ſouth-eaſt wind, which is regularly ſucceeded

ceeded by the north-east. At Saint Domingo, there are two different winds that rise regularly every day; the one, which is from the sea, comes from the east, and begins at 10 o'clock before noon; the other, which is a land-wind, from the west, rises at 6 or 7 in the evening, and continues the whole night. Other facts of this kind, collected from voyagers of knowledge and credit, might furnish a complete history of the winds, which would be a work extremely useful both in navigation and physics.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XV.

Of Irregular Winds, Hurricanes, Water-Spouts, and other Phænomena, occasioned by the agitations of the Sea, and of the Air.

THE winds are more irregular on the land than on the sea, and in high than in low countries. The mountains not only change the direction of the winds, but even produce some, which are either constant or variable, according to their causes. The melting of snows on the tops of mountains generally give rise to constant winds, which last a considerable time. The vapours that strike against the mountains, and accumulate upon them, produce variable winds, which are very common in all climates; and there is as great a variety in the motions of the

the air, as there are inequalities on the ſurface of the earth. We can, therefore, give examples only, and a genuine hiſtory of facts: And, as a connected ſeries of obſervations upon the variations of the winds, and even of the ſeaſons, in different countries, is ſtill wanting, we ſhall not attempt to explain all the cauſes of theſe variations, but ſhall confine ourſelves to thoſe which are moſt probable.

In ſtraits, at the extremities of promontories, peninſulas, and capes, and in all narrow bays, tempeſtuous winds are frequent. But, independent of theſe, ſome ſeas are much more infeſted with ſtorms than others. The Indian Ocean, the ſeas of Japan and of Magellan, along the African coaſt beyond the Canaries, and the oppoſite coaſt near Natal, and the Red and Vermilion Seas, are all ſubject to tempeſts. The Atlantic is likewiſe more tempeſtuous than the great ocean called the Pacific: This laſt ocean, however, is no where perfectly tranquil, except between the Tropics; for the nearer we approach the Poles, it is the more ſubject to variable winds, the ſudden changes of which produce tempeſts.

All continents are ſubject to the effects of variable winds, which are ſometimes very ſingular. In the kingdom of Caſſimir, which is ſurrounded with the mountains of Caucaſus, a moſt ſudden reverſe of ſeaſons is felt on Mount Pirepenjale. In leſs than an hour's journey, we paſs from ſummer to winter: A north and a ſouth

 wind,

wind, according to Bernier, blow perceptibly within 200 paces of each other. The poſition of this mountain muſt be ſingular; and, therefore, it merits a particular examination. In the peninſula of India, which is traverſed from north to ſouth by the mountains of Gate, the extreme heats of ſummer are felt on one ſide of theſe mountains, and all the rigours of winter on the other. The ſame phænomenon takes place on the two oppoſite coaſts of Cape Roſalgate in Arabia: On the north coaſt the ſea is calm and tranquil; while the ſouth coaſt is infeſted with continual ſtorms. Ceylon exhibits another example of this phænomenon. Winter and high winds reign in the north part of the iſland, while, on the ſouth ſide of it, fine weather and ſummer heats prevail. Of oppoſite ſeaſons in the neighbourhood of each other, and at the ſame time, there are ſeveral examples, not only on the continent, but on the iſlands, as at Cerem, a long iſland near Amboyna, in the north part of which it is winter, and ſummer in the ſouth part; and the interval between theſe two ſeaſons is not above three or four leagues.

In Egypt a ſouth wind prevails during ſummer, which is ſo hot as to ſtop reſpiration; and it raiſes ſuch immenſe quantities of ſand, that the ſky ſeems to be covered with thick clouds. This ſand is ſo fine, and is blown with ſuch violence, that it penetrates the cloſeſt cheſts. When this wind continues for ſeveral days, it gives riſe

to

to epidemic diſeaſes, which frequently cut off vaſt numbers of men. It ſeldom rains in Egypt; every year, however, there are ſome days of rain in the months of December, January, and February. But thick fogs are more frequent than rain, eſpecially in the neighbourhood of Cairo. Theſe fogs commence in November, and continue during the winter; and, through the whole year, even when the ſky is ſerene, the dews fall ſo copiouſly, that they have all the effects of rain.

In Perſia, the winter commences in November, and laſts till March. The cold is ſtrong enough to produce ice; and ſnows fall in the mountains, and ſometimes in the plains. From March to May, there are violent winds, which recal the warmth of ſummer. From May to September the ſky is ſerene, and the heats are moderated during the night by freſh breezes which continue till morning; and, in autumn, there are violent winds, like thoſe which blow in the ſpring. However, though theſe winds are very ſtrong, they ſeldom produce tempeſts or hurricanes. But, in ſummer, a very noxious wind blows along the Perſic Gulf, which is called *Samiel* by the natives; it is ſtill hotter and more terrible than that of Egypt; and, as it acts like an exploſion of inflamed vapour, it ſuffocates every perſon who unhappily falls within its vortex. A ſimilar wind riſes in ſummer along the Red Sea, which ſuffocates animals, and

transports such quantities of sand, that many people imagine this sea will, in the course of time, be completely filled up. Arabia gives birth to frequent clouds of sand which darken the air, and excite dangerous whirlwinds. At Vera Cruz, when the hot winds blow from the north, the houses of that town are almost buried with sand. Hot winds are also felt in summer at Negapatan in India, and likewise at Petapouli and Masulapatan. These scorching winds which kill men are fortunately of no long duration; but they are extremely violent, and their heat and deleterious quality are proportioned to their velocity, which is contrary to the nature of other winds; for the more their rapidity, they are the more wholesome and refreshing. This difference proceeds from the degree of heat in the air. When the heat of the air is less than that of the body, the motion of the air is agreeable. But, when the heat of the air is greater than that of the bodies of animals, its motion scorches and suffocates. At Goa, the winter, or rather the rainy and tempestuous season, is in the months of May, June, and July, and it cools and refreshes the air, which would otherwise be perfectly insupportable in that region.

The Cape of Good Hope is famous for its tempests, and a peculiar cloud which produces them. This cloud at first appears like a small round spot in the heavens, which mariners distinguish

ſtinguiſh by the name of the *Ox's Eye.* The ſeeming ſmallneſs of this cloud is probably owing to its great height. Of all voyagers who mention this cloud, Kolbe appears to have examined it with the greateſt attention. 'This 'cloud,' ſays he*, 'which appears on the moun-'tains of the *Table*, or of the *Devil*, or of the '*Wind*, is compoſed, if I am not deceived, of an 'infinite number of particles puſhed, in the firſt 'place, againſt the mountains to the eaſt of the 'Cape, by the eaſt wind which blows in the 'Torrid Zone during almoſt the whole year. 'Theſe particles or vapours are ſtopped by the 'high mountains, and are collected on their 'eaſt ſide. They then become viſible in the 'form of ſmall fragments of clouds, which, by 'the conſtant action of the eaſt wind, are ele-'vated to the tops of the mountains. Here 'they remain not long at reſt; but, being forced 'to advance, they ſink down between the 'mountains which are ſtill before them, where 'they are locked up and ſqueezed on all ſides 'as in a canal. The wind preſſes theſe vapours 'from above, and the oppoſite ſides of the two 'mountains confine them on the right and left, 'till, in their progreſs, they advance to the foot 'of ſome mountains where the country is more 'flat and open; they then expand, and become 'again inviſible. But they are ſoon puſhed 'againſt another ridge of mountains by freſh

* Tom. i. p. 224.

 clouds

'clouds coming up behind them; and in this 'manner they proceed till they arrive with vaſt 'impetuoſity at the top of the higheſt moun-'tains of the Cape, which are thoſe of the '*Wind* or of the *Table*, where they are met by a 'wind blowing in the very oppoſite direction. 'Here a dreadful conflict enſues. The vapours 'are preſſed both before and behind, which pro-'duces terrible whirlwinds, either on the moun-'tains of the *Table*, or in the valleys. When the 'north-weſt wind yields, that of the ſouth-eaſt 'increaſes, and continues to blow with more or 'leſs violence for ſix months. When the *Ox's* '*Eye* is thick, the force of the ſouth-eaſt wind 'augments, becauſe the vapours amaſſed behind 'the mountains continually preſs forward; for 'the ſame reaſon, this wind diminiſhes when 'the *Ox's Eye* is thin; and it entirely ceaſes 'when the *Ox's Eye* vaniſhes, becauſe no va-'pours arrive from the eaſt.

'The circumſtances attending this phænomenon 'menon lead to the following hypotheſis: '1. Behind the mountain of the *Table*, a train 'of thin white vapour is obſerved, which com-'mences on the eaſtern declivity of this moun-'tain, ends in a ſharp point at the ſea, and occu-'pies, in its extent, the whole mountains of '*Stone*. I have often contemplated this train, 'and imagined it to originate from the rapid 'motion of the vapour above deſcribed, from 'the mountains of *Stone* to thoſe of the *Table*.

'2. The

'2. The paſſage of theſe vapours muſt be extremely embarraſſed by the contrary ſhocks received, not only from the mountains, but from the ſouth and eaſt winds which prevail in the neighbourhood of the Cape. I have already mentioned the two mountains ſituated on the points of *Falſe Bay*, the one called the *Hanging Lip*, the other the *Norvege*. When the particles or vapours, which I have conjectured, are puſhed againſt theſe mountains by the eaſt winds, they are repelled by the ſouth winds and driven againſt the neighbouring mountains, where they are detained for ſome time, and appear like clouds, as they often do upon the mountains of *Falſe Bay*, and even beyond them. Theſe clouds are frequently very thick above the land in the poſſeſſion of the Dutch, upon the mountains of *Stellenboſck*, of *Drakenſtein*, and of *Stone*, but eſpecially upon the mountains of the *Table* and of the *Devil*.

'Laſtly, The conſtant appearance of ſmall black clouds upon the *Lion's Head* two or three days before the ſouth-eaſt wind blows, confirms me in my conjecture; for theſe clouds, in my opinion, are compoſed of the particles or vapour mentioned above. If the north-weſt wind prevails when theſe particles arrive, their courſe is ſtopped; but they are never driven to any great diſtance till the ſouth-eaſt wind commences.'

The navigators who firſt approached the Cape of Good Hope, were ignorant of the effects of theſe

these clouds, which seemed to arise slowly and without any agitation in the air, but which, in a moment, excite the most furious tempests, and precipitate the largest vessels to the bottom of the ocean. In the country of Natal, a cloud, similar to the Ox's Eye at the Cape, produces the same direful effects. These species of tempests are frequent in the Atlantic, especially in the neighbourhood of the Equator. Near the coast of Guiney, three or four of these storms sometimes happen in a day, which are likewise occasioned and announced by small black clouds, while the rest of the sky is generally serene, and the sea perfectly calm. It is principally in April, May, and June, that these furious storms arise along the coast of Guiney, because no regular winds blow there at that season. On the coast of Loango, the stormy season is in the months of January, February, March, and April. At Cape Gardafu, on the other side of Africa, they have storms of this kind in May, and the clouds which produce them are generally in the north, like those of the Cape of Good Hope.

All these storms originate from winds which issue from a cloud; and their direction is from north to south, or from north-east to south-west, &c. But there are tempests of another kind, called Whirlwinds, which are still more violent, and in which the wind seems to blow from every quarter at once. Their motion is circular, and nothing can resist their fury. They are generally

generally preceded by a dead calm; but, in an inſtant, the waves are elevated to the clouds by the fury of the winds. Some parts of the ſea cannot be approached; becauſe they are perpetually infeſted either with calms or whirlwinds. Theſe places have been called *calms* and *tornados* by the Spaniards. The moſt conſiderable of them are near Guiney, about the 2d or 3d degree of north latitude. They extend about 300 or 350 leagues in length, and nearly as much in breadth, which includes a ſpace of more than 100,000 ſquare leagues.

When contrary winds arrive at the ſame time in the ſame place, they produce whirlwinds, by the oppoſite motion of the air, in the ſame manner as whirlpools are produced in the ſea by contrary currents. But when theſe oppoſite winds are counterbalanced by their diſtant action upon each other, they then revolve in a great circle, and produce a perfect calm, which it is impoſſible for veſſels to navigate. Theſe places are all marked in the globes of Mr. Senex. I am inclined to think, that the contrariety of winds alone, if not aſſiſted by the direction of the coaſt, and the particular ſtructure of the bottom of the ſea in theſe places, could not produce this effect. I imagine that the currents, which are in effect occaſioned by the winds, but aſſume their direction from the figure of the coaſts and the inequalities at the

 bottom,

bottom, terminate in these places; and that their opposite motions, in a plain surrounded with a chain of mountains, give rise to the tornados in question.

Whirlpools seem to be nothing else but circular motions of the waters occasioned by the action of two or more opposite currents. The Euripus, so famed by the death of Aristotle, alternately absorbs and rejects the water seven times every 24 hours. This whirlpool is near the coast of Greece. Charybdis, which lies near the straits of Sicily, rejects and absorbs the water thrice in 24 hours. We are uncertain as to the number of alternate motions in other whirlpools. Dr. Placentia informs us, that the motions of the Euripus are irregular for 18 or 19 days every month, and regular during the other 11; and that it seldom swells above one, or at most two feet. He farther informs us, that authors are not agreed as to the tides in the Euripus; that some say it is twice, others seven times, some 11, others 12 or 14 times in 24 hours; but that Loirius, who examined it attentively, found that the tides rose regularly every six hours, and that their motion was sufficient to turn a mill-wheel.

The largest known whirlpool is in the sea of Norway, the circumference of which exceeds 20 leagues. It absorbs, for six hours, water, whales, ships, and any thing that approaches it, and

and the next ſix hours are employed in throwing them up again.

To account for theſe whirlpools, it is unneceſſary to have recourſe to an abyſs, or to pits in the bottom of the ſea, which are perpetually ſwallowing the waters. It is well known, that, when water runs in two directions, the combination of theſe motions produces a whirling, and exhibits the appearance of a void ſpace in the middle. In the ſame manner, whirlpools in the ſea are occaſioned by two or more contrary currents, and, as the tides are the principal cauſe of currents, and, of courſe, they run for ſix hours in contrary directions, it is not ſurpriſing, that the whirlpools which are produced by them ſhould alternately reject and abſorb every thing within their reach during the ſame portion of time.

Whirlpools, then, are occaſioned by contrary currents, and whirlwinds by the conflict of contrary winds. Theſe whirlwinds are common in the Chineſe and Japaneſe ſeas, near the Antilles, and in many other places of the ocean, particularly in the neighbourhood of prominent coaſts. But they are ſtill more frequent upon land; and their effects are ſometimes prodigious. 'I have ſeen,' ſays Bellarmin *, 'an enormous 'ditch ſcooped out by the wind, tranſported in 'the air, and dropped upon a village, which was 'for ever buried under this load of earth.' A detail of the effects of ſeveral hurricanes may be

* De Aſcenſu Mentis in Deum.

ſeen

ſeen in the Hiſtory of the French Academy, and in the Philoſophical Tranſactions, which would appear altogether inconceivable, if they were not atteſted by intelligent and credible ſpectators.

The ſame obſervation may be made with regard to water-ſpouts, which the mariner never beholds without terror and amazement. They are common on certain coaſts of the Mediterranean, eſpecially when the weather is cloudy, and the wind blows from ſeveral quarters at the ſame time. They are more frequent near the coaſts of Laodicea, of Grecgo, and of Carmel, than in any other part of the Mediterranean. Moſt of them are large cylinders of water which fall from the clouds, though, at a diſtance, the water appears to riſe up from the ſea to the clouds*.

But there are two ſpecies of water-ſpouts; the firſt is that we have juſt mentioned, and is nothing but a thick cloud compreſſed, and ſurrounded by oppoſite winds blowing from different quarters at the ſame time, which make it aſſume a cylindric figure, and fall down by its own gravity. The quantity of water is ſo immenſe, and the rapidity of the fall ſo great, that if, unfortunately, one of theſe ſpouts break upon a ſhip, it is daſhed to pieces, and ſinks in an inſtant. It is alledged, and with probability, that water-ſpouts may be broken and diſſipated by the commotion excited in the air by the

* See Shaw's Travels.

firing

ſiring of cannons, which correſponds with the diſſipation of thunder-clouds by the ringing of bells.

The other ſpecies of water-ſpout is called a *typhon*, and is very frequent in the Chineſe Sea. The typhon deſcends not from the clouds, nor is it produced by the action of oppoſite winds. On the contrary, it riſes from the water to the heavens with amazing rapidity. Whirlwinds often run along conſiderable tracts, bearing down houſes, trees, and every obſtacle that they meet with. But typhon's remain always in the ſame places, and can be owing to nothing but ſubterraneous fires; for the ſea is then in the greateſt agitation, and the air is ſo impregnated with ſulphureous exhalations, that the ſky appears to be covered with a copper-coloured cruſt, although there be no clouds, and the ſun or the ſtars appear through the vapour. It is to theſe ſubterranean fires that we muſt aſcribe the warmth of the Chineſe Sea in winter, where theſe typhons are very frequent*.

Thevenot, in his voyage to the eaſt, gives the following account of water-ſpouts: 'We ſaw 'water-ſpouts in the Perſic gulf, between the 'iſlands of Queſomo, Lareca, and Ormutz. Few 'have had the opportunity of obſerving, and 'fewer ſtill have paid the attention to water-'ſpouts, that I have done. I ſhall deſcribe them

* See Acta erud. Lipſ. ſupplem. tom. i. p. 405.

'with

'with perſpicuity and ſimplicity, in order to 'render my account the more intelligible.

'The firſt that we ſaw, was on the north ſide 'between us and the iſland of Queſomo, about 'a gun-ſhot from our ſhip. In this place, we 'ſaw the water begin to boil, and to be raiſed 'about a foot above the ſurface: It was whitiſh, 'and the top of it appeared like black ſmoke: 'It made a kind of whiſpering noiſe, like a tor'rent ruſhing down with violence into a deep 'valley. This noiſe was mingled with another 'that reſembled the hiſſing of ſerpents. A little 'afterwards, we ſaw an obſcure canal or pipe, 'which reſembled ſmoke riſing to the clouds, 'and revolved with conſiderable velocity: This 'pipe was about the ſize of a man's finger; and 'the ſame noiſe continued. It then vaniſhed, 'having continued in all about a quarter of an 'hour. We then perceived another on the 'ſouth, which began in the ſame manner as the 'former: Immediately a third ſprung up to the 'weſt, and then a fourth likewiſe to the weſt; 'the moſt diſtant from us not exceeding a muſket'ſhot. Each of them appeared like heaps of 'ſmoking ſtraw, and were accompanied with 'the ſame noiſe as the firſt. We next perceiv'ed three pipes, or canals, extending from the 'water to the clouds, where each of them ter'minated like the mouth of a funnel or trum'pet, or like the paps of an animal drawn per'pendicularly downward by a weight. Theſe

'pipes

'pipes were of a dark white colour, which I 'imagined to be owing to the water they con- 'tained; for the pipes appeared to be formed 'before they were filled with the water, and 'they disappeared when they were empty; in 'the same manner as a cylinder of clear glass, 'when held up in the light at a distance from 'the eye, is not visible, unless it be filled with 'some coloured liquor. These pipes were not 'straight, but bent in some places: They were 'not even perpendicular; on the contrary, from 'the clouds into which they were ingrafted, to 'the places from which they extracted the wa- 'ter, they were very much inclined. And, 'what is singular, the cloud to which the second 'of the three was attached, having been pushed 'forward by the wind, the pipe followed it 'without breaking, or quitting its station in the 'water; and, passing behind the pipe of the first, 'they remained for some time in the form of a 'St. Andrew's cross. At first, none of the three 'exceeded an inch in thickness, except where 'they joined the cloud: But the one that ap- 'peared first, swelled afterwards considerably. 'The other two continued not longer than the 'one we had seen to the north. The second, 'on the south, lasted about a quarter of an 'hour; but the first, on the same side of the 'vessel, continued longer, and gave us some un- 'easiness. Concerning it, therefore, we have still 'farther to remark, that, although it originally

'was not larger than a man's finger, it gradually 'swelled to the size of an arm, then to that of a 'leg, and, *lastly*, to that of the trunk of a tree as 'large as a man could encompass with both his 'arms. We saw the water rising distinctly 'through this transparent body, which was of a 'serpentine form; and it sometimes diminished in 'thickness both above and below. It now ex-'actly resembled a soft tube filled with water, 'and pressed with the fingers, either above to 'make the fluid descend, or below to make it 'ascend; and I was satisfied that these variations 'were occasioned by the wind, which, when it 'pressed the canal above, caused the water to de-'scend, and when the pressure was lower down 'made the water ascend. After this, it dimi-'nished to the size of a man's arm; then it swel-'led to the size of a thigh; then became ex-'ceedingly small; *lastly*, I perceived that the 'water elevated from the surface began to sink, 'and the end of the canal separated from it; 'when a variation of the light removed it from 'my view. I still, however, continued to look 'for it, because I had remarked, that the canal 'of the second spout appeared to break in the 'middle, and to reunite a little afterwards, one 'half of it having been concealed by the light; 'but this last never more appeared.

'These spouts are exceedingly dangerous at 'sea; for, when they fall upon a vessel, they 'mingle so with the sails, that they sometimes

'raise

'raiſe the veſſel up, and let it fall back again 'with ſuch violence as to ſink it. But, although 'they ſhould not raiſe the ſhip, they tear the 'ſails, or let the whole water they contain fall 'upon the veſſel, which precipitates it to the 'bottom. It is not improbable, that many veſ-'ſels, of which we never have any accounts, 'periſh by ſuch accidents, for there are few 'examples of our ever learning with certainty 'of ſhips being loſt in this manner.'

The above account of water-ſpouts ſeems to have proceeded from ſeveral optical illuſions. But I have related the facts *verbatim*, that they may either be confirmed, or at leaſt compared, with thoſe of other navigators. M. Gentil, in his voyage round the world, deſcribes water-ſpouts in the following manner: 'At eleven o'clock, 'before noon, the ſky being cloudy, we ſaw 'around our ſhip, at the diſtance of about a quar-'ter of a league, ſix water-ſpouts, which began 'with a noiſe like that of water running below 'ground, and gradually increaſed till it reſembled 'the hiſſing noiſe occaſioned by a high wind 'among the ropes of a ſhip. We firſt perceived 'that the ſea began to boil; and its ſurface roſe 'about a foot and a half; the top of this ele-'vated part was covered with a thick fog, or 'rather ſmoke, which formed itſelf into a canal, 'and mounted to the clouds. Theſe canals 'bended according as the wind carried the 'clouds to which they were attached. Not-

 'withſtanding

'withſtanding the motion communicated to the
'clouds by the wind, the canals not only ad-
'hered to them, but ſeemed to ſtretch out, or
'contract, in proportion as the clouds roſe high-
'er, or ſunk down in the atmoſphere.

'Theſe appearances gave us much uneaſineſs;
'and our ſailors, inſtead of encouraging each
'other, increaſed their fears by dreadful ſtories.
'If theſe ſpouts, ſaid they, fall upon the ſhip,
'they will lift her up, and then plunge her to
'the bottom. Others maintained, with a deci-
'ſive tone, that they would not lift the veſſel;
'but that, being full of water, if the ſhip went
'forward, ſhe would break their communication
'with the ſea, and that the great body of water,
'by falling perpendicularly on the veſſel, would
'break her in pieces.

'To prevent this misfortune, they lowered
'the ſails, and charged the cannon. It is a ge-
'neral opinion among ſailors, that the firing of
'cannon, by agitating the air, burſts and diſ-
'perſes water-ſpouts. But we were not under
'the neceſſity of having recourſe to this expedi-
'ent; for, after courſing round the ſhip for
'about ten minutes, ſome being about a quarter
'of a league from us, and others nearer, the
'canals became gradually narrower, detached
'themſelves from the ſurface of the ſea, and then
'entirely vaniſhed *.'

* Tom. i. p. 191.

From

From the deſcription of theſe two voyagers, it appears, that water-ſpouts are produced, at leaſt in part, by the action of fire or ſmoke, which riſes with violence from the bottom of the ſea; and that they are very different from thoſe which are occaſioned by oppoſite winds: 'The 'water-ſpouts,' ſays Mr. Shaw*, which I had 'the opportunity of ſeeing, ſeemed to be ſo 'many cylinders of water falling down from the 'clouds; though, by the reflection, it may be 'of thoſe deſcending columns, or from the actual dropping of the water contained in them, 'they would ſometimes appear, eſpecially at a 'diſtance, to be ſucked up from the ſea. Nothing 'more, perhaps, is required to explain this phænomenon, than that the clouds ſhould be firſt 'of all crouded together, and then, that contrary 'winds, preſſing violently upon them, ſhould 'occaſion them to condenſe, and fall in this cylindrical manner.'

Many facts remain ſtill to be known before theſe phænomena can be properly explained. To me it, appears, that, if there be, in particular places, at the bottom of the ſea, a mixture of ſulphur, bitumen, and mineral ſubſtances, theſe may occaſionally be inflamed, which will produce, like the exploſion of gun-powder, a great quantity of air; and that this air newly generated, and rarefied to a prodigious degree, mounts with rapidity, and may elevate the water from

* Shaw's Travels, p. 334.

the ſea to the clouds. In the ſame manner, if a perpendicular current of air be produced by the exploſion of ſulphureous matter in a cloud, the whole of its water may follow this current, and give riſe to a water-ſpout from the clouds to the ſea. But, it muſt be acknowledged, that this account of the laſt ſpecies of ſpout is not more ſatisfactory than that which we have given of thoſe produced by contrary winds; for, it may be aſked, why thoſe ſpouts, which originate from the clouds, are not as common on land as upon the ſea?

The hiſtorian of the academy for the year 1727, mentions a land water-ſpout that appeared at Capeſtan near Beziers. It deſcended from a cloud like a black pillar, which gradually diminiſhed, and ended in a point upon the ſurface of the earth. It followed the direction of the wind, which was weſterly; it was attended with a thick ſmoke, and made a noiſe like the ſea when greatly agitated. It tore up trees by the roots, and marked its way on the earth by a large tract in which three carriages might have paſſed each other. Another pillar of the ſame kind appeared, but it ſoon joined the firſt; and, when the whole was diſſipated, there fell a great quantity of hail.

This ſpecies of water-ſpout appears to be different from the other two. It is not ſaid to have contained water; and it ſeems, both from what I have mentioned, and by M. Andoque's explication

cation of it to the academy, to have been only a hurricane rendered viſible by the duſt and condenſed vapour which it contained. The ſame hiſtorian, for the year 1741, mentions a water-ſpout which was ſeen upon the lake of Geneva. It was of a cylindrical figure, the upper part of which ended in a black cloud, and the under part of it was narrow, and terminated near the ſurface of the water. This meteor continued only a few minutes; and, at the moment of its diſſipation, a thick vapour aſcended from the place where it firſt appeared; the water of the lake boiled, and ſeemed to make an effort to riſe into the air, which was very calm the whole time; neither was this ſpout followed either by wind or rain. 'After all our knowledge of water-'ſpouts,' ſays the hiſtorian, 'does not this prove 'that they are not produced by the conflict of 'oppoſite winds alone, but that they almoſt al-'ways originate from volcano's or ſubterrane-'ous vapours, which are known to exiſt at the 'bottom of the ſea, as well as upon land? 'Whirlwinds and hurricanes, therefore, which 'are generally believed to be the cauſe of theſe 'appearances, may be only an effect or an acci-'dental conſequence of them.'

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XVI.

Of Volcano's and Earthquakes.

THE bowels of those burning mountains called *Volcano's* contain sulphur, bitumen, and other inflammable materials, the effects of which are more violent than those of thunder or of gun-powder; and they have, in all ages, astonished mankind, and desolated the earth. A volcano is an immense cannon, with an aperture often more than half a league in circumference. From this vast mouth are projected torrents of smoke and of flames, rivers of bitumen, of sulphur, and of melted metals, clouds of ashes and stones; and sometimes it ejects, to the distance of several leagues, rocks so enormous, that they could not be moved by any combination of human

man force. The conflagration is ſo dreadful, and the quantities of burning, calcined, melted, and vitrified ſubſtances thrown out by the mountain, are ſo great, that they bury whole towns and foreſts, cover the plains to the thickneſs of a hundred or two hundred feet, and ſometimes form hills and mountains, which are only portions of theſe matters heaped up and compacted into one maſs. The action of the fire and the force of the exploſions are ſo violent, that they produce by reaction, ſuccuſſions, which ſhake the earth, agitate the ſea, overturn mountains, and deſtroy towns and buildings of the moſt ſolid materials.

Theſe effects, though natural, have been regarded as prodigies; and, though we often behold, in miniature, effects ſimilar to thoſe of volcano's; yet grandeur, from whatever ſource it proceeds, has ſuch an aſtoniſhing influence upon the imagination, that it is not ſurpriſing they ſhould have been conſidered by ſome authors as vents to a central fire, and, by the vulgar, as mouths of hell. Aſtoniſhment produces fear, and fear is the ſource of ſuperſtition. The inhabitants of Iceland believe that the groanings of their volcano are the cries of the damned, and that its eruptions are occaſioned by the deſperation and ungovernable fury of devils and tormented ſpirits.

All theſe phænomena, however, are only the effects of fire and of ſmoke. In the bowels of mountains,

mountains, there are veins of ſulphur, bitumen, and other inflammable ſubſtances, together with vaſt quantities of pyrites, which ferment when expoſed to the air or moiſture, and produce exploſions proportioned to the quantity of inflammable matter. This is the true idea of a volcano; and it is eaſy for the naturaliſt to imitate the operation of theſe ſubterraneous fires. A mixture of ſulphur, of filings of iron, and of water, buried at a certain depth below the ground, will exhibit, in miniature, all the appearances of a volcano: This mixture ſoon ferments to a degree of inflammation, throws off the earth and ſtones which cover it, and produces exploſions every way ſimilar to thoſe of burning mountains.

The moſt famous volcano's in Europe are thoſe of Mount Ætna in Sicily, of Mount Hecla in Iceland, and of Mount Veſuvius, near Naples in Italy. The burning of Mount Ætna is more ancient than the records of hiſtory. Its eruptions are extremely violent; and the quantity of matter it throws out is ſo enormous, that, after digging 68 feet deep, marble pavements, and other veſtiges of an ancient city, have been found covered with this amazing load of ejected matter, in the ſame manner as the town of Herculaneum has been buried with the matter thrown from Mount Veſuvius. New mouths, or ſiters, were opened in Ætna in the years 1650, 1669, and at other times. The ſmoke and flames

flames of this volcano are ſeen as far as Malta, a diſtance of 60 leagues: It ſends forth a perpetual ſmoke, and, at particular times, it throws out, with aſtoniſhing violence, flames, lava, huge ſtones, and matter of every kind. An eruption of this volcano, in the year 1537, produced an earthquake over the whole iſland of Sicily, which laſted 12 days, and overthrew an immenſe number of houſes and public buildings. It terminated by the burſting of a new mouth, the lava of which burnt up every thing within five leagues of the mountain. It diſcharged aſhes ſo abundantly, and with ſuch force, that they reached the coaſt of Italy, and incommoded veſſels at great diſtances from the iſland. This volcano has, at preſent, two principal craters, one of which is narrower than the other. They both ſmoke perpetually; but flames only appear during the time of eruptions. Large ſtones, it is ſaid, have been projected from them to the diſtance of 60,000 paces.

A violent eruption, in 1683, produced a dreadful earthquake in Sicily. It laid the whole city of Catanea in ruins, and deſtroyed more than 60,000 of its inhabitants, beſide thoſe who periſhed in the neighbouring towns and villages.

Hecla darts its fires through the ſnows and ice of a frozen climate. Its eruptions, however, are equally violent with thoſe of Ætna, and other volcano's in the more ſouthern regions. It throws out aſhes, lava, pumice-ſtones, and

ſometimes boiling water. The whole iſland of Iceland abounds in ſulphur ; but it is not habitable within leſs than ſix leagues of the volcano. The hiſtory of its moſt violent eruptions is recorded in a book written by *Dithmar Bleffken.*

According to hiſtorians, the burning of Mount Veſuvius began not before the ſeventh conſulate of Titus Veſpaſian and Flavius Domitian. The top of the mountain then opened, and at firſt threw out ſtones and rocks. Theſe were ſucceeded by flames and lava which burnt up two neighbouring cities, and volumes of ſmoke ſo thick as to darken the light of the ſun. The elder Pliny, ſtimulated by curioſity, approached too near the mountain, and was ſuffocated by its ſulphureous ſteams*. Dion Caſſius relates, that this eruption was ſo violent, that aſhes and ſulphureous ſteams were tranſported as far as Rome, and acroſs the Mediterranean into Africa and Egypt. Heraclea was one of the cities that were overwhelmed by the matter ejected from the mountain: It has lately been diſcovered 60 feet under the ſurface of the ground, which, in the courſe of time, had become arable, and fit for every kind of culture. The hiſtory of the diſcovery of Heraclea is in the hands of the public. We have only to wiſh, that ſome perſon, ſkilled in the knowledge of nature, would examine with attention the different materials which compoſe theſe 60 feet of earth, and remark their

* See Pliny the Younger's Letter to Tacitus.

ſituation,

ſituation, the alterations they have undergone, the direction they have followed, the hardneſs they have acquired, &c.

Naples appears to be ſituated upon a vault, filled with burning minerals; for Veſuvius and Solfatara ſeem to have ſubterraneous communications. When Veſuvius throws out lava, Solfatara emits flames; and, when the eruptions of the former ceaſe, the burning of the latter is likewiſe extinguiſhed. The city of Naples is nearly in the centre between them.

One of the laſt and moſt dreadful eruptions of Veſuvius happened in the year 1737*. The mountain diſcharged, from ſeveral mouths, immenſe torrents of melted matter, which ſpread over the fields, and terminated in the ſea. M. de Montealegre, who communicated this account of it to the Academy of Sciences, obſerved, with horror, one of theſe rivers of fire, which, from its ſource to the ſea, was about 7 miles in length, 50 or 60 paces broad, from 25 to 30 palms deep, and in the valleys 120 palms. The running matter reſembled foam, or the droſs which iſſues from a furnace †, &c.

In Aſia, and particularly in the iſlands of the Indian ocean, volcano's are numerous. One of the moſt famous is Mount Albours, near Mount Taurus, about 8 leagues from Herat. The top of

* This volume was publiſhed in the year 1749. Several eruptions have happened ſince that time. See Hamilton's Hiſtory of Veſuvius.

† See l'Hiſt. de l'Acad. année, 1737, p. 7.

of this mountain ſends forth a perpetual ſmoke; and it frequently throws out flames and burning matter, in ſuch quantities as to cover all the adjacent plains with aſhes. In the iſland of Ternate, there is a volcano which diſcharges matter ſimilar to pumice-ſtones. Some voyagers allege, that this volcano is moſt furious during the equinoxes, becauſe theſe periods are attended with certain winds which increaſe the inflammation of thoſe fires that have continued to burn for ages*. The iſland of Ternate is not above 7 leagues round, and is only the top of a large mountain. The land riſes from the coaſt to the middle of the iſland, where the volcano mounts to a height ſo great, that it is difficult to climb to its top. Several rills of ſweet water deſcend from the ſides of the mountain; and, when the air is calm, and the weather fine, this burning gulf is leſs agitated than during ſtorms and high winds †. This is a confirmation of what I formerly remarked, and ſeems to prove, that the fire of volcano's proceeds not from a great depth, but from the top or higher parts of the mountain; for, if it were otherwiſe, high winds could not increaſe the violence of the flames.

There are other volcano's in the Molucca iſlands. In one of the iſlands of Mauritius, about 70 leagues from the Moluccas, there is a volcano, the effects of which are equally violent as thoſe

* See Voyages d'Argenſola, tom. i. p. 21.

† See Voyage de Schouten.

of the mountain at Ternate. The iſland of Sorca, one of the Moluccas, was formerly inhabited. In the middle of this iſland there is a very high mountain, with a volcano at its ſummit. In 1693, this volcano diſcharged an immenſe quantity of bitumen, and inflamed matter, which, after forming a burning lake, gradually extended till it covered the whole iſland *.

There are ſeveral volcano's in Japan, and the adjacent iſlands, which ſend out flames in the night, and ſmoke in the day. In the Philippine iſlands, there are likewiſe ſeveral burning mountains. One of the moſt remarkable, and, at the ſame time, the moſt recent volcano in the Indian iſlands, is that near the town of Penarucan in the iſland of Java. It commenced in the year 1586, and, at the firſt eruption, it threw out immenſe quantities of ſulphur, bitumen, and ſtones. The ſame year, Mount Gounapi, in the iſland of Banda, which had been a volcano about 17 years only, opened and ejected, with a dreadful noiſe, rocks and matter of every kind. There are ſtill other volcano's in India, as in Sumatra, and in the north of Aſia, beyond the river Jeniſcea, and the river Peſida: But the two laſt are little known.

Near Fez in Africa, there is a mountain, or rather a cavern, called *Beni-guazeval*, which conſtantly throws out ſmoke, and ſometimes flame. One of the Cape de Verd iſlands, called

* See Phil. Tranſ. Abridg. vol. ii. p. 391.

the

the iſland of *Fuogo*, is nothing but a huge mountain which burns inceſſantly. This volcano throws out ſtones and aſhes; and the Portugueſe, who often attempted to inhabit the iſland, have always abandoned the project, on account of the volcano. The Peak of Teneriff, which is reckoned one of the higheſt mountains in the world, throws out fire, aſhes, and large ſtones. From the top of it, rivulets of melted ſulphur run down the ſouth ſide acroſs the ſnows. This ſulphur ſoon condenſes, and forms veins in the ſnow, which are diſtinguiſhable at great diſtances.

America, and particularly the mountains of Mexico and Peru, are much infeſted with volcano's: That of Arequipa is one of the moſt celebrated: It often produces great earthquakes, which are more frequent in Peru than in any country of the world. Next to Arequipa, the volcano's of Carrappa and Malahallo are, according to the relation of travellers, the moſt conſiderable. But there are many others in the new world of which we have no knowledge. M. Bouguer, in his voyage to Peru, publiſhed in the Memoirs of the Academy for the year 1744, mentions two volcano's, the one called *Cotopaxi*, and the other *Pichincha*. The firſt is at ſome ance from, and the other very near, the town Quito. In the year 1742, he ſaw an eruption of Cotopaxi, which, at that time, burſt open a new mouth in the mountain. It did no

other damage than that of melting the ſnow, and producing ſuch torrents, as, in three hours, laid the whole country, to the extent of 18 leagues, under water, and overturned every thing in their courſe.

Popochampeche and Popocatapec are the chief volcano's in Mexico. It was near this laſt that Cortes paſſed in his way to the city of Mexico: Some of the Spaniards aſcended to the top of the mountain, where they found the crater to be about half a league in circumference. Sulphureous mountains have alſo been found in Guadaloupe, Tercera, and in others of the Azore iſlands; and, if all the mountains from which ſmoke or flames iſſue were to be conſidered as volcano's, their number would exceed 60. We have only mentioned thoſe which are ſo formidable as, by their frequent eruptions, to prevent people from living near them.

The numerous volcano's in the Cordeliers, as I formerly remarked, produce almoſt perpetual earthquakes, which prevent the inhabitants from building with ſtone any higher than the firſt floor; and the upper parts of their houſes, for the ſame reaſon, are conſtructed with ruſhes or very light wood. In theſe mountains there are alſo many precipices and large gulfs, the walls of which are black and burnt: They are ſimilar to the precipice of Mount Ararat in Armenia, called the *Abyſs*, and are the craters of extinguiſhed volcano's.

 A late

A late earthquake at Lima was attended with the moſt dreadful effects. The town of Lima, and the port of Callao, were almoſt entirely ſwallowed up. But the miſchief was ſtill more terrible at Callao. The ſea roſe and covered every houſe in that unfortunate town, and drowned the whole inhabitants, leaving only a ſingle tower as a monument of its devaſtations. Of 25 veſſels which lay in the harbour, four were driven a league upon land, and the reſt were ſwallowed up by the waves. Of Lima, which was a very large city, only 27 houſes remained ſtanding. Multitudes of people periſhed; and the diſaſter was particularly fatal to the monks and other religious, becauſe their buildings were lofty and of more ſolid materials than the common houſes. This calamity happened in the month of October 1746, during the night; and the ſucceſſion laſted 15 minutes.

Near the port of Piſca, in Peru, there was formerly a famous city, ſituated on the ſea-coaſt; but, on the 19th of October 1682, it was almoſt entirely deſtroyed by an earthquake; for the ſea, having exceeded its uſual limits, ſweeped away this unfortunate city, with all its inhabitants.

By conſulting hiſtorians and travellers, we ſhall find many accounts of earthquakes, and eruptions of volcano's, equally dreadful and deſtructive as thoſe we have mentioned. Peſi-

donius,

donius, quoted by Strabo *, relates, that a city of Phœnicia, near Sidon, was ſwallowed up by an earthquake, with the neighbouring territory, and two thirds of Sidon itſelf; that this effect was not produced ſo ſuddenly as to prevent the inhabitants from eſcaping by flight; that it extended over moſt of Syria, and as far as the Cyclades iſlands and Eubœa, where the fountains of Arethuſa ſuddenly ſtopped, and appeared a few days afterwards by new ſources, at a conſiderable diſtance from the old; and that the earthquake continued to ſhake the iſland ſometimes in one place, and ſometimes in another, till the earth opened in the valley of Lepanta, and diſcharged a great quantity of burning matter. Pliny informs us †, that, in the reign of Tiberius, twelve cities in Aſia were overturned; and he mentions ‡, in the following terms, a prodigy occaſioned by a violent earthquake. 'Factum eſt ſemel (quod equidem in 'Etruſcæ diſciplinæ voluminibus inveni) ingens 'terrarum portentum, Lucio Marco, Sex. Julio Coſſ. in agro Mutinenſi. Namque montes duo inter ſe concurrerunt, crepitu maximo adſultantes recedenteſque, intor eos flamma, fumoque in cœlum exeunte interdiu, ſpectante e via Æmilia magna equitum Romanorum familiarumque et viatorum multitudine. Eo concurſu villæ omnes eliſæ, animalia permulta, quæ intra fuerunt, exanimata ſunt,' &c.

* Lib. 1. † Lib. 1. c. 84. ‡ Lib. 2. c. 83.

St. Auguſtin tells us*, that, in Lybia, 100 towns were deſtroyed by an earthquake. In the time of Trajan, the earth opened and devoured the city of Antioch, and a great part of the adjacent country. It was again deſtroyed by the ſame cauſe during the reign of Juſtinian in the year 528, and 40,000 of its inhabitants periſhed. It was viſited with a third earthquake in the days of St. Gregory, ſixty years after the former, which deſtroyed no leſs than 60,000 of its inhabitants. In the reign of Saladin, *anno* 1182, moſt of the cities of Syria and of Judea were laid waſte by the ſame calamity. Earthquakes have been more frequent in Apulia and Calabria than in any other part of Europe. In the time of Pope Pius II. all the churches and palaces of Naples were thrown down, and about 30,000 lives were loſt: Thoſe who eſcaped were obliged to live in tents till houſes were built for them. In 1629, 7000 perſons periſhed in Apulia by earthquakes; and, in 1638, the city of Saint Euphemia was ſwallowed up, and left behind it nothing but a ſtinking lake: At the ſame time, Raguſa and Smyrna were almoſt totally deſtroyed. In 1692, an earthquake was felt in Britain, Holland, Flanders, Germany, and France: It was moſt ſevere along the coaſts of the ſea, and near great rivers. It agitated at leaſt 2600 ſquare leagues, though it laſted but two minutes. The commotion was greater in the

* Lib. 2. de miraculis, c. 3.

the mountains than in the valleys*. 'On the 10th of July 1688, there was an earthquake at Smyrna, which began with a motion from weſt to eaſt. The caſtle was firſt overturned; its four walls ſeparated from each other, and ſunk ſix feet in the ſea. This caſtle ſtood formerly on an iſthmus, which is now a real iſland, about 100 paces from the land. The eaſt and weſt walls fell; but the north and ſouth walls ſtill remain. The city, which is near 10 miles from the caſtle, was overthrown ſoon after. The earth opened in many places, attended with ſubterraneous noiſes; and five or ſix dreadful ſhocks were felt before the approach of night, the laſt of which laſted about half a minute. The ſhips in the roads were greatly agitated; the ground on which the town ſtood ſunk two feet; and not above a fourth of the houſes withſtood the concuſſion, and thoſe were moſtly founded on rock. From fifteen to twenty thouſand lives were loſt†. In 1695, an earthquake was felt at Bologna in Italy; and it was remarked, as a ſingular phænomenon, that the ſea was much troubled the day preceding‡.

'On the 4th of May 1614, a terrible earth-'quake happened at Tercera, which, beſide 'private houſes, overturned eleven churches 'and nine chapels in the city of Angra; and 'the city of Praya was ſo much ſhaken, that

* See Ray's Diſcourſes, p. 272. † See l'Hiſt. de l'Acad. des Sciences, année 1688. ‡ Ibid. année 1696.

'hardly a house was left standing: And, on 'the 15th of June 1628, the island of St. Mi-'chael was visited with a great earthquake. 'Near this island, in the open sea, there arose 'a new island in a place where the water was '150 fathoms deep. This island was more 'than a league and a half long, and above six 'fathoms high *.

'In the island of St. Michael, another earth-'quake began on the 26th of July 1691, and 'continued to the 12th of the following month. 'Tercera and Fayal were shaken next day with 'such violence, that they seemed to turn about. 'These concussions, however, were repeated 'there only four times: But, at St. Michael, 'they ceased not a moment during the space 'of eleven days. The islanders abandoned their 'houses, which every where tumbled down be-'fore their eyes, and remained the whole time 'in the open fields, exposed to the injuries of 'the weather. The whole town of Villa Fran-'ca was overturned to the foundation, and half 'of the inhabitants were buried under its ruins. 'In several places, the plains were elevated into 'hills, and, in others, the hills sunk down into 'valleys. A fountain of fresh water issued from 'the ground, and run for four days, and then 'stopped all of a sudden. The air and the sea ere in such commotion, that they made a noise resembling the bellowings of ferocious

* See Mandelslo's Voyages.

'animals,

'animals. Many people died of fear. There 'was not a veſſel in the harbours which was 'not agitated in a dangerous manner; and thoſe 'which lay at anchor, or were under ſail, at 'the diſtance of twenty leagues, were ſtill more 'ſeverely toſſed. Earthquakes are very fre- 'quent in the Azores: Twenty years before the 'period mentioned, a mountain in St. Michael 'was overturned by a dreadful earthquake*.

'In the month of September 1627, an earth- 'quake levelled one of the two mountains of 'Manilla, called *Carvalos*, in the province of 'Cagayon. In 1645, a third part of the city 'was deſtroyed by a ſimilar accident, and 300 'perſons periſhed in the ruins. The following 'year it was viſited by another; and the old 'Indians tell us, that earthquakes are now leſs 'deſtructive than formerly; but they ſtill build 'their houſes of wood, in which they are imi- 'tated by the Spaniards.

'The number of volcano's in this iſland con- 'firms the above relation; for, at certain inter- 'vals, they vomit forth flames, ſhake the earth, 'and produce all the effects aſcribed by Pliny 'to the eruptions of Veſuvius, ſuch as, chang- 'ing the beds of rivers, making the neighbour- 'ing parts of the ſea retreat, covering the 'places adjacent with aſhes, projecting ſtones to 'great diſtances, and making reports louder 'than thoſe of cannons†.'

* Gen. Hiſt. of Voyages, vol. i. p. 325. † See Voyage de Gemelli Carreri, p. 129.

'In 1646, an earthquake split a mountain in 'the island of Machian, and the explosion made 'a frightful noise. From the cleft issued such 'a quantity of flames as consumed several plan-'tations with their inhabitants. This prodi-'gious aperture was to be seen in the year 1685, 'and it probably remains to this day. It was 'called the *Wheel-track* of Machian, because it 'ran from the top to the bottom of the moun-'tain, and, at a distance, had the appearance of 'a high road*.'

The history of the French Academy mentions, in the following terms, the earthquakes which happened in Italy during the years 1702 and 1703. 'They began in October 1702, and 'continued till July 1703. The city of Norcia, 'with its dependencies in the ecclesiastical state, 'and the province of Abruzzo, suffered most; 'and the earthquakes were first felt in those 'places which are situated at the foot of the 'Appennines, on the south side.

'They were frequently accompanied with 'frightful noises in the air, and these noises 'were sometimes heard when the earth was at 'rest, and the sky serene. The most violent 'concussion was on the 2d of February 1703; 'and it was attended, especially at Rome, with 'a remarkable clear sky, and a great calmness 'in the air.' At Rome it lasted half a minute, and at Aquila, the capital of Abruzzo, three

* See l'Hist. de la Conquête des Moluques, tom. iii. p. 318.

'hours.

'hours. Beside ravaging the neighbouring coun-
'try, it destroyed the whole town of Aquila,
'and buried 5000 persons under its ruins.

'The concussions, or vibrations, of the earth, 'as was discovered by the motion of the lamps 'in the churches, were nearly from south to 'north.

'The earth opened in two places, and dis-'charged, with violence, great quantities of 'stones, which covered a whole field, and ren-'dered it barren. After the stones, these aper-'tures threw up water above the elevation 'of the highest trees. This discharge continued 'a quarter of an hour, and laid the neighbour-'ing country under water. The water was 'whitish, like soap-suds, and had no particular 'taste.

'On the top of a mountain near Sigillo, a 'village about 22 miles from Aquila, there was 'a considerable plain surrounded with rocks 'like a wall. The earthquake of the 2d of 'February converted this plain into a large 'unequal gulf, its greatest diameter being 25 'fathoms, and its least 20. This gulf has been 'sounded with ropes of 300 fathoms, without 'reaching the bottom. At the time that the 'gulf was formed, flames were observed to issue 'out of the mountain, and afterwards a thick 'smoke, which continued, with some interrup-'tions, for three days.

'At

'At Genoa they had two slight concussions 'of the 1st and 2d days of July 1703, the last 'of which was only felt by the people on the 'Mole. The sea, at the same time, sunk 6 feet 'in the port, and continued in this situation a 'quarter of an hour.

'The sulphureous water on the road between 'Rome and Tivoli sunk two feet and a half, 'both in the basin and in the canal. The springs 'and rills of water, which rendered many places 'of the plain called *Testine* marshy, were entirely 'dried up. The depth of the water in the lake 'called *l'Enfer* was diminished three feet. In 'place of the old springs, new ones, about a mile 'distant, appeared: They are probably the same 'waters, the courses of which have been changed 'by the concussion of the earth*.'

The same earthquake, which, in 1538, formed the Monti de Cinere near Puzzoli, filled the Lucrin lake with stones, earth, and ashes, and converted it into a marsh †.

'Earthquakes, also,' says Mr. Shaw, 'have 'sometimes been felt at sea. In the year 1724, 'when I was aboard the Gazella, an Algerine 'cruiser of 50 guns, bound to Bona to relieve 'the garrison, we felt three prodigious shocks, 'one after another, as if a weight, at each time, 'of 20 or 30 ton, had fallen from a great height 'upon the ballast. This happened when we

* See l'Hist. de l'Acad. des Sciences, année 1704.

† See Ray's Discourses, p. 12.

were

'were five leagues to the ſouthward of the Seven 'Capes, and could not reach ground with a line 'of 200 fathom. The captain told me, that, a 'few years before, when he was upon a cruiſe, 'he felt a much greater one, at the diſtance of '40 leagues to the weſtward of the rock of Liſ-'bon *.'

Schouten, ſpeaking of an earthquake which happened in the Moluccas, ſays, that the mountains were ſhaken, and that the veſſels at anchor in 30 or 40 fathom water, were ſhocked, as if they had run aſhore, or ſtruck againſt rocks. 'We learn,' continues he, 'from daily experi-'ence, that the ſame happens in the ocean, where 'no bottom can be found; and that earth-'quakes agitate veſſels, even when the ſea is 'perfectly calm †.'

Gentil, in his voyage round the world, has the following remarks upon earthquakes: '1. 'That, half an hour before the earth begins 'to ſhake, all animals appear to be ſeized with a 'panic. The horſes neigh, break their halters, 'and run out of the ſtable; the dogs bark; the 'birds, as if ſtupid, fly for ſhelter into the 'houſes; the rats and mice come out of their 'holes, &c. 2. That ſhips at anchor are ſo 'violently agitated, that all the parts of which 'they are compoſed ſeem to be torn aſunder; 'their guns break looſe, and their maſts ſpring. 'Theſe facts I ſhould hardly have credited, if

* Shaw's Travels, p. 151.
† Voyages, vol. vi. p. 103.

'they had not been confirmed to me by the 'unanimous teſtimony of many witneſſes. I 'know that the bottom of the ſea is a continu-'ation of the land; and that agitations of the 'one muſt be communicated to the other; but 'I could not comprehend how the different 'parts of a veſſel, ſwimming in a fluid, ſhould 'be affected in the ſame manner as if ſhe had 'been reſting on the ground. Her motion, I 'imagined, ſhould have only reſembled that 'produced by a ſtorm; beſides, in the preſent 'inſtance, the ſurface of the ſea was ſmooth, 'and the whole agitation muſt have proceeded 'from ſome internal cauſe, becauſe, at the time 'of the earthquake, there was no wind. 3. 'That, if the cavern of the earth which con-'tains the ſubterraneous fire, runs from north to 'ſouth, and if the buildings of a town above it 'lie in the ſame direction, the whole houſes are 'overturned; but, if the vein or cavern runs 'acroſs the town, the damage produced by 'earthquake is leſs conſiderable *.'

When a new volcano breaks out in countries ſubject to earthquakes, they almoſt entirely ceaſe, and are ſeldom felt, except during great erup-tions, as has been obſerved with regard to the iſland of St. Chriſtophers †.

The enormous ravages produced by earth-quakes have induced ſome naturaliſts to imagine,

* See Voyage de M. le Gentil, tom. i. p. 172.

† See Phil. Tranſ. abridg. vol. ii. p. 392.

that

that mountains, and all the other irregularities on the ſurface of the globe, have derived their origin from ſucceſſions of the earth occaſioned by the action of ſubterraneous fires. This, for inſtance, is the opinion of Mr. Ray. He believes that all the mountains have been formed by earthquakes, or by the exploſions of volcano's, in the ſame manner as Monti de Cinere in Italy, the new iſland near Santorini, &c. But he has not conſidered, that the ſmall elevations formed by earthquakes, or by the eruptions of volcano's, are not, like all other mountains, compoſed of horizontal ſtrata; for, by digging into the Monti de Cinere, we find calcined ſtones, aſhes, burnt earth, iron-droſs, pumice-ſtones, all blended together like a heap of rubbiſh. Beſides, if earthquakes and ſubterraneous fires had raiſed the great mountains of the earth, as the Cordeliers, Mount Taurus, the Alps, &c. the prodigious force requiſite to elevate theſe enormous maſſes would, at the ſame time, have deſtroyed a great part of the ſurface of the globe. Earthquakes ſufficient to produce ſuch effects muſt have been inconceivably violent, ſince the greateſt of them recorded in hiſtory have not been able to produce a ſingle mountain. In the reign of Valentinian I. for inſtance, an earthquake was felt over the whole known world*, and yet it raiſed not a ſingle mountain.

* Ammian. Marcellin. lib. xxvi. c. 14.

It

It is capable of demonſtration, however, that though an earthquake ſhould have a force ſufficient to raiſe the higheſt mountains, this force would not be able to diſplace the reſt of the globe.

For, let it be ſuppoſed, that the chain of high mountains which traverſe South America from the point of Terra Magellanica to New Granada and the Gulf of Darien, had been ſuddenly elevated by an earthquake, and then let us eſtimate the effect of this exploſion. This chain of mountains is about 1700 leagues long, and, at a medium, 40 leagues broad, including the Sierres, which are lower than the Andes. This gives a ſurface of 68,000 ſquare leagues. The thickneſs of the matter diſplaced by the earthquake I ſuppoſe to be one league; or, that the mean height of the mountains from their ſummits to the caverns, which, agreeable to this hypotheſis, muſt ſupport them, is one league. The force of the exploſion, therefore, muſt have elevated, to the height of a league, a quantity of earth equal to 68,000 cubic leagues. But, action and reaction being equal, this exploſion muſt have communicated an equal quantity of motion to the whole globe. Now, the whole globe conſiſts of 12,310,523,801 cubic leagues. From this number take 68,000, and there remains 12,310,455,801 cubic leagues, of which the quantity of motion would be equal to that of 68,000 elevated one league. Hence it appears, that

that the force neceſſary to raiſe 68,000 cubic leagues would not be ſufficient to diſplace the whole globe a ſingle inch.

There is no abſolute impoſſibility, therefore, in the ſuppoſition, that the mountains have been raiſed by earthquakes, were it not evident, both from their internal ſtructure and their external figure, that they have been formed by the operation of the waters of the ocean. Their interior parts are compoſed of parallel ſtrata, interſperſed with ſea-ſhells; and their external figure conſiſts of angles every where correſponding. Is it credible that this uniform ſtructure, and regular figure, could have been produced by ſudden and deſultory ſuccuſſions of the earth?

But, as this notion has been embraced by ſome philoſophers, and, as the nature and effects of earthquakes are not well underſtood, I ſhall hazard a few ideas, which may, perhaps, throw ſome light upon this intricate ſubject.

The ſurface of the earth has undergone many changes. At conſiderable depths, we find holes, caverns, ſubterraneous rivulets, and voids, which ſometimes communicate with each other by means of chinks and fiſſures. There are two ſpecies of caverns: The firſt are thoſe which have been formed by volcano's and the action of ſubterraneous fires. The action of ſubterraneous fire elevates, ſhakes, and throws off to a diſtance the ſuperincumbent materials; at the ſame time, it ſplits and deranges thoſe on each

 ſide

fide of it, and thus produces caverns, grottos, and irregular hollows. But fuch effects are only exhibited in the neighbourhood of volcano's, and are not fo frequent as the other fpecies of caverns which are produced by the operation of water. It has already been remarked, that the different ftrata of the earth are all interrupted by perpendicular fiffures, the origin of which fhall be afterwards explained. The waters which fall upon the furface defcend through thofe fiffures, collect when their progrefs is prevented by a ftratum of clay, and form fprings and rivulets. From the nature of water, it fearches for cavities or fmall vacuities, and has a conftant tendency to force a paffage, till it finds a proper vent. Wherever it goes, it carries along with it fand, gravel, and other bodies which it is capable of dividing or diffolving. In this manner, the operation of water proceeds till it forms fubterraneous paffages; and then it breaks out in the form of fountains, either on the furface of the earth, or in the bottom of the fea. The materials it perpetually carries off leave hollows or caverns in the bowels of the earth, which are often of great extent; and thefe caverns have a very different origin from thofe produced by volcano's or earthquakes.

Earthquakes are of two kinds: Thofe occafioned by the action of fubterraneous fires, and by the explofions of volcano's, are only felt at fmall diftances, previous to, or during the time

time of eruptions. When the inflammable matters in the bowels of the earth begin to ferment and to burn, the fire makes an effort to escape in every direction; and if it finds no natural vents, it forces a passage, by elevating and throwing off the incumbent earth. In this manner volcano's commence, and their effects continue in proportion to the quantity of inflammable matter they contain. When the quantity of inflamed matter is inconsiderable, it produces only an earthquake, and exhibits no marks of a volcano: The air generated by subterraneous fire may also escape through small fissures; and, in this case, likewise, it will be attended with a succussion of the earth; but no volcano will appear. But when the quantity of inflamed matter is great, and when it is confined on all sides by solid and compact bodies, an earthquake and a volcano are the necessary consequences. All these commotions, however, constitute only the first species of earthquakes, which are not felt but in the neighbourhood of the places where they happen. A violent eruption of Ætna, for example, will shake all the island of Sicily; but it will never extend to the distance of three or four hundred leagues. When Vesuvius bursts open a new mouth, it excites an earthquake in Naples and in the neighbourhood of the volcano; but these earthquakes never shake the Alps, nor do they extend to France or other countries distant from Vesuvius. Thus, earthquakes produced

by volcano's are limited to a ſmall ſpace; they are nothing but effects of the reaction of the fire, and they ſhake the earth in the ſame manner as the exploſion of a powder-magazine occaſions an agitation to the diſtance of ſeveral leagues.

But there is another ſpecies of earthquakes, which are very different in their effects, and perhaps alſo in their cauſe. Theſe earthquakes are felt at great diſtances, and ſhake a long tract of ground without the intervention either of a new volcano, or of eruptions in thoſe which already exiſt. There are inſtances of earthquakes which have been felt at the ſame time in Britain, in France, in Germany, and in Hungary. Theſe earthquakes always extend more in length than in breadth. They ſhake a zone or belt of earth with greater or leſs violence in different places; and they are generally accompanied with a hollow noiſe, like that of a heavy carriage rolling with rapidity.

As to the cauſes of this ſpecies of earthquake, it muſt be remarked, that the exploſion of all inflammable ſubſtances, like that of gun-powder, generates a great quantity of air; that this air is highly rarefied by heat; and that its effects, from the compreſſion it receives by being confined in the bowels of the earth, muſt be exceedingly violent. Let us ſuppoſe, that, at the depth of 100 or 200 fathoms, there are a vaſt collection of pyrites and ſulphureous bodies, and that they are inflamed by the fermentation produced

duced by the admiſſion of water to them, or by other cauſes. What muſt be the effect? In the firſt place, theſe ſubſtances are not placed in horizontal beds, like the ancient ſtrata, which were formed by the ſediments of the waters. They are lodged, on the contrary, in the perpendicular fiſſures, in ſubterraneous caverns, and other places, to which the water has acceſs. When inflamed, they generate a vaſt quantity of air, the ſpring of which, by being compreſſed within a ſmall ſpace, like that of a cavern, will not ſhake the earth immediately above, but it will ſearch for paſſages in order to expand and make its eſcape. Caverns and channels of ſubterraneous rivulets and ſprings, are the only natural paſſages for this rarefied air. Into theſe, therefore, it will ruſh with impetuoſity, and produce in them a furious wind, the noiſe of which will be heard on the ſurface; and it will be attended with vibrations or ſuccuſſions of the ground. This ſubterraneous wind produced by fire will extend the whole length of the caverns or channels, and occaſion a ſhaking, more or leſs violent, in proportion to its diſtance from the heat, and to the width or narrowneſs of the canals. But this motion muſt neceſſarily run in a longitudinal direction; and the ſhaking, of courſe, muſt be felt over a long belt of ground. This air, however, cannot produce an eruption or a volcano, becauſe it finds ſufficient room for expanding itſelf, and diminiſhing its force; or, rather, becauſe it eſcapes through fiſſures in

the form of vapour or of wind. But, although the existence of caverns or channels for the passage of this rarefied air should be denied, it is easy to conceive, that in the very place where the explosion is made, as the earth is elevated to a considerable height, the neighbouring places must split horizontally in attempting to yield to the impulse communicated by the original motion; and, in this manner, passages may be gradually and successively opened, so as to communicate with very distant places. This explication corresponds with all the phænomena. Earthquakes are not felt at great distances at the same minute, or even the same hour. They are not accompanied with eruptions or external fire; and the noise almost constantly marks the progressive motion of the subterraneous wind. Other facts concur in establishing this theory. Blasts of wind, and vapours, sometimes of a suffocating nature, it is well known arise from mines, independent of the motion of the air produced by the current of water. It is equally well known, that winds issue from certain apertures of the earth, from caverns, abysses, and deep lakes, as Lake Boleslaw in Bohemia, which has been formerly mentioned.

When these remarks are considered, I cannot comprehend how the mountains should have originated from earthquakes, since the mineral and sulphureous bodies which occasion them are seldom to be met with but in the perpendicular

lar fiſſures of mountains, and in other cavities of the earth, the greateſt number of which have been produced by the operation of water; ſince theſe inflammable ſubſtances produce only a momentary exploſion, and violent winds which follow the channels of ſubterraneous waters; ſince the duration of earthquakes on the ſurface of the earth is ſo ſhort, they muſt be occaſioned by a ſudden exploſion, and not by a continued conflagration; and, *laſtly*, ſince thoſe earthquakes, which extend over large tracts of ground, never produce the ſmalleſt eminence throughout their whole courſe.

Earthquakes, it is true, are more frequent in the neighbourhood of volcano's, as in Sicily, and the environs of Veſuvius: But it appears, from repeated obſervations, that theſe earthquakes are very limited, and, conſequently, can never form a chain of mountains.

It has ſometimes been remarked, that the matters ejected from Ætna, after cooling for ſeveral years, and being afterwards moiſtened with rain, have rekindled, and thrown out flames with ſuch violent exploſions, as to occaſion ſmall earthquakes.

In 1669, during a violent eruption of Ætna, which began on the 11th of March, the ſummit of the mountain ſunk conſiderably*; which is a proof that this volcano proceeds rather from the ſuperior part of the mountain than from

* See Phil. Tranſ. Abridg. vol. ii. p. 387.

the bottom of it. Borelli, who is of the ſame opinion, obſerves, 'That the fire of a volcano proceeds 'neither from the centre, nor from the bottom of 'a mountain, but from the top; and that the inflammation never kindles but at a ſmall depth *.'

Mount Veſuvius has frequently thrown out, during eruptions, great quantities of boiling water. Mr. Ray, who imagines that the fire of volcano's comes from a very great depth, ſays, that this water proceeds from the ſea, which communicates, by ſubterraneous paſſages, with the foot of the mountain. As a proof, he mentions the remarkable dryneſs of the top of Veſuvius, and the agitation of the ſea during eruptions, which ſometimes recedes ſo far as to leave the port of Naples entirely dry. But, ſuppoſing theſe facts to be true, they by no means prove that the fire of volcano's proceeds from a great depth; for the water they eject is certainly rain-water, which penetrates through the fiſſures, and collects in the cavities of the mountain. Rills and ſprings iſſue from the tops of volcano's, as well as from other high mountains; and, as the former are hollow, and have ſuffered more concuſſions than the latter, nothing can be more natural than they ſhould collect water in their caverns, and that theſe waters ſhould ſometimes be ejected, along with other ſubſtances, in the time of eruptions. With regard to the motion of the ſea, it ariſes ſolely from the ſhock com-

* Borelli de incendiis Montis Ætnæ.

municated

municated to the waters by the explosion, which makes them advance or retire according to different circumstances.

The most common substances thrown out by volcano's, are torrents of melted minerals, which overflow the environs of the mountain. These rivers of lava extend to great distances; and, in cooling, they form beds, either horizontal or inclined, in the same manner as the strata accumulated by successive sediments from water. But the former are easily distinguishable from the latter: 1. Because strata of lava are not every where equal in thickness. 2. Because they contain nothing that has not evidently been calcined, vitrified, or melted. 3. Because their extent is more limited. As there is a vast number of volcano's in Peru, and as the bottoms of most of the Cordeliers are covered with substances which have been thrown out by eruptions, it is not surprising that no sea-shells have been found there; for they must have been calcined and destroyed by the fire. But I am still persuaded, that, if the clay ground, which, according to M. Bourguet, is the ordinary earth in the valley of Quito, had been dug, shells would have been discovered there, as well as every where else, especially where the ground is not covered, like the bottoms of the mountains, with matters ejected from volcano's.

It has often been asked, Why all volcano's appear in high mountains only? I have partly

 solved

ſolved this queſtion in the preceding article. But, before finiſhing the preſent ſubject, I ſhall endeavour more fully to explain myſelf.

The peaks or points of mountains were originally covered with earth and ſand, which, after being gradually waſhed down to the valleys by the rains, left nothing but thoſe bare rocks or ſtones called the core of mountains, which, being likewiſe ſubjected to the action of the weather, ſmall and large fragments of them muſt have been occaſionally looſened, and, of courſe, muſt have rolled down to the plains. The rocks at the baſe of the ſummit being fully uncovered, and having loſt their original ſupport from the ſand and earth, would neceſſarily give way a little, and, by ſeparating from each other, would produce ſmall intervals. But this yielding of the lower rocks could not take place without rending thoſe which lay above them. In this manner the core of the mountain, from the ſummit to the baſe of the lower rocks, would be ſplit into an infinite number of perpendicular fiſſures of different dimenſions. Through theſe the rains would penetrate, and carry along with them, into the bowels of the mountain, all the minerals, and other ſubſtances which they were capable of tranſporting or diſſolving. Here pyrites, ſulphur, and other combuſtible ſubſtances, would be produced; and, in the courſe of time, theſe bodies would accumulate in great quantities, and, by their fermentation, would give riſe to explo-

ſions and other effects of volcano's. Heaps of theſe mineral ſubſtances might likewiſe exiſt in the heart of the mountain, before the rain could penetrate ſo deep. In this caſe, as ſoon as the air or rain got acceſs to them by means of the perpendicular fiſſures, a conflagration and volcano would inſtantly take place. No ſuch phænomena can be exhibited in plains; for, as every thing there is at reſt, and nothing can be diſplaced, it is not ſurpriſing that the exiſtence of volcano's ſhould be confined entirely to the mountains.

When coal-mines are opened, which are commonly found in clay-grounds, and at a great depth, the mineral ſubſtances above mentioned ſometimes kindle into flames. There are examples in Scotland, Flanders, &c. of coal-mines which have continued to burn for many years. The admiſſion of air is alone ſufficient to produce this effect. But theſe inflammations occaſion only ſlight exploſions, and never form volcano's; becauſe, in ſuch places, all being plain and ſolid, the fire cannot be excited to ſuch a degree as in burning mountains, which are full of caverns and cliffs, through which the air penetrates, and augments the action of the fire ſo forcibly, as to give riſe to the terrible effects we have been deſcribing.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XVII.

Of New Islands, Caverns, perpendicular Fissures, &c.

NEW islands are produced either suddenly by the operation of subterraneous fires, or slowly by the accumulated sediments of water. Upon this subject we are furnished with indubitable facts, both by ancient historians, and by modern voyagers. Seneca tells us, that, in his time, the island of Therasia* suddenly emerged from the sea, to the astonishment of many spectators. Pliny relates, that 13 islands formerly arose all at once from the bottom of the Mediterranean, and that Rhodes and Delos are the chief of them. According to Ammianus Marcellinus, Philo, Pliny, &c. these 13 islands were

* Now called Santorini.

not formed by an earthquake or by a ſubterraneous exploſion, but were formerly concealed under the water, which ſunk and uncovered them. Delos was even diſtinguiſhed by the name of Pelagia, becauſe it formerly belonged to the ſea. Whether theſe 13 new iſlands were produced by the action of ſubterraneous fire, or by any other cauſe which diminiſhed the quantity of water in the Mediterranean, it is not eaſy to determine. But we are informed by Pliny himſelf, that the iſland of Hiera, in the neighbourhood of Theraſia, is compoſed of ferruginous maſſes, and of earth which had been thrown up from the bottom of the ſea; and, in another place, he mentions ſeveral other iſlands which had been formed in the ſame manner. Upon this ſubject, however, we have facts more recent, and leſs involved in obſcurity.

On the 23d day of May 1707, at ſun-riſing, there appeared, at the diſtance of two or three miles from the iſland of Theraſia or Santorini, ſomething which had the reſemblance of a floating rock. Some men, ſtimulated by curioſity, approached it, and diſcovered that it had ariſen from the bottom of the ſea; that it increaſed under their feet; that oyſters and other ſhells ſtill adhered to the rocks; and that many pumice-ſtones lay on its ſurface. Two days before this rock appeared, there had been a ſlight earthquake Santorini. This iſland continued to augment conſiderably, without any accident, till the 14th of

of June. It was then about half a mile in circumference, and 20 or 30 feet high, and the earth was white and mixed with clay. After this time, the ſea began to be more and more agitated; vapours aroſe from it which infeſted the iſland of Santorini, and on the 16th of July, 17 or 18 rocks roſe all at once from the bottom of the ſea, and united into one maſs. Theſe phænomena were attended with a frightful noiſe, which continued two months; and flames iſſued from the new iſland, which ſtill augmented both in circumference and height; and the exploſions were ſo violent, that they drove large ſtones to more than 7 miles diſtance. The iſland of Santorini itſelf was regarded by the ancients as a recent production; and, in 726, 1427, and 1573, it received conſiderable additions, beſide the ſmall iſlands formed in its neighbourhood*. The ſame volcano, which, in the days of Seneca, raiſed the iſland of Santorini, produced, in Pliny's time, that of Hiera or Volcanella, and, in our days, the rock above deſcribed.

On the 10th of October 1720, a great fire was ſeen to ariſe from the ſea near the iſland of Tercera. Navigators being ſent, by order of government, to examine it, they perceived, on the 19th of the ſame month, an iſland covered with fire and ſmoke; and a prodigious quantity of aſhes was thrown to a great diſtance, as from a volcano, and accompanied with a noiſe ſimilar to tha

* See l'Hiſt. de l'Acad. des Sciences, 1708, p. 23.

of thunder. The earth was alſo perceived to ſhake in the neighbourhood; and a vaſt number of pumice-ſtones were found floating on the ſea all round the new iſland: This laſt phænomenon has ſometimes been remarked in the open ſea*.

The hiſtorian of the French academy†, in relating this event, remarks, that, after an earthquake in the iſland of St. Michael, one of the Azores, there appeared a torrent of fire between this iſland and that of Tercera, which gave riſe to two new rocks: And, in the ſubſequent year, the ſame hiſtorian gives the following detail:

'M. de l'Iſle has informed the academy of ' ſeveral particulars concerning the new iſland ' among the Azores, which he received in a ' letter from M. de Montagnac conſul at Liſ- ' bon. On the 18th of September 1721, M. de ' Montagnac's veſſel was moored off the fortreſs ' of St. Michael; and he learned the following ' particulars from the pilot of the port.

'During the night of the 7th or 8th of De- ' cember 1720, there was a great earthquake in ' Tercera and St. Michael, which iſlands are diſ- ' tant from each other about 28 leagues, and a ' new iſland roſe from the ſea. It was, at the ' ſame time, remarked, that the point of the ' iſland of Peak, at the diſtance of 30 leagues,

* See Philoſophical Tranſact. Abridg. vol. vi. part 2. p. 154.

† Ann. 1721, p. 26.

' which

'which formerly threw out flames, was extinguished. But a continual thick ſmoke iſſued from the new iſland, which was diſtinctly perceived by M. de Montagnac, as long as he continued in that part. The pilot aſſured him, that he had ſailed round the iſland, and approached it as near as he could with ſafety. He ſounded on the ſouth ſide of it with a rope of 60 fathoms; but found no bottom. On the weſt ſide, the water was much changed: It appeared to be mixed with white, blue, and green; and, at the diſtance of two miles, it ſeemed to be ſhallow and boiling. On the north-weſt, the ſide from which the ſmoke iſſued, he found, at 15 fathoms, a bottom of coarſe ſand. He threw a ſtone into the ſea, and, at the place where it fell, he obſerved the water boil, and mount into the air with great impetuoſity. The bottom was ſo hot, that, at two different times, it melted a piece of ſuet which had been faſtened to the end of the plumb-line. The pilot likewiſe remarked, that ſmoke iſſued from a ſmall lake, in the midſt of a ſandy plain. This iſland is nearly round, and high enough to be perceived, in clear weather, at the diſtance of ſeven or eight leagues.

'We have ſince learned, by a letter from M. Adrien, French conſul at St. Michael, dated in March 1722, that the new iſland is conſiderably diminiſhed; that it is nearly on a

'level

'level with the water; and that it will probably
'soon disappear.'

From these, and many other facts of a similar nature, it is apparent, that inflammable bodies exist under the bottom of the sea, and that they sometimes produce violent explosions. The places where they happen may be considered as submarine volcano's, which differ from common volcano's only in the shorter duration of their effects; for, after the fire opens a passage to itself, the water rushes in, and extinguishes them. The elevation of new islands necessarily leaves caverns, which are soon filled by the waters; and the new ground, which consists of matter thrown out by the submarine volcano, must, in every respect, resemble that of the Monti di Cinere, and other eminences which have been raised by terrestrial volcano's. It is on account of the waters rushing into the voids and fissures produced by explosions, that submarine volcano's exhibit their effects less frequently than common volcano's, though both derive their origin from the same cause.

To subterraneous, or rather submarine, fires, must be ascribed all those ebullitions of the sea, and water-spouts, which have been remarked in different places by mariners: They also produce storms and earthquakes, the effects of which are felt equally at sea as upon land. The islands raised by submarine volcano's are generally composed of pumice-stones and calcined rocks.

Fire

Fire has frequently been obſerved to iſſue out of the waters of the ſea. Pliny tells us, that the whole ſurface of the Thraſymen lake has appeared to be inflamed; and Agricola informs us, that, when a ſtone was thrown into the lake of Denſtat in Thuringia, its deſcent was marked by a train of fire.

Laſtly, The great quantities of pumice-ſtones diſcovered by voyagers in different parts of the ocean, as well as in the Mediterranean, evince the exiſtence of volcano's in the bottom of the ſea, which differ not from thoſe upon land, either in the violence of their exploſions, or in the matter they throw out, but only in their rarity, and in the ſhortneſs of their duration. Hence it may be remarked, that the bottom of the ſea every way reſembles the ſurface of the earth, not admitting even the exception of volcano's.

Between ſea and land volcano's there are many relations. Both of them exiſt on the tops of mountains. The Azore iſlands, and thoſe of the Archipelago, are only the points of mountains, ſome of which are above, and others under, the ſurface of the water. From the account of the new iſlands among the Azores, it appears, that the place where the ſmoke iſſued was only 15 fathoms deep, which, when compared with the ordinary depth of the ocean, demonſtrates this place to be the top of a pretty high mountain. The ſame remark may be

made

made with regard to the new iſland near Santorini. Its depth muſt have been inconſiderable, ſince oyſters were found attached to the rocks which roſe above the ſurface of the water. It likewiſe appears, that ſea-volcano's, as well as thoſe upon land, have ſubterraneous communications; for, at the very time that the new iſland among the Azores aroſe, the ſummit of the volcano of St. George, in the iſland of Peak, ſunk. It alſo merits obſervation, that new iſlands never appear but in the neighbourhood of old ones; and that there are no examples of new iſlands in open ſeas: They ought, therefore, to be regarded as continuations of the ancient iſlands; and, when volcano's happen to exiſt in the latter, it is not ſurpriſing that the former ſhould contain the ſame materials, which may be kindled either by fermentation alone, or by the action of ſubterraneous winds.

Beſides, new iſlands produced by earthquakes, or by ſubterraneous fires, are few in number. But the number of thoſe formed by ſlime, ſand, and earth, tranſported by rivers, or by the motions of the ſea, is almoſt infinite. At the mouths of rivers, ſuch quantities of earth and ſand are amaſſed, as frequently give riſe to iſlands of conſiderable extent. The ſea, by retiring from certain coaſts, leaves uncovered the higheſt parts of the bottom, and theſe parts conſtitute ſo many new iſlands. In the ſame manner, when the ſea encroaches upon the land, it

covers the plains, and the more elevated grounds appear in the form of iſlands. It is for this reaſon that there are few iſlands in the open ſeas, and that they are ſo numerous near the coaſts.

Fire and water, though of very oppoſite natures, exhibit many effects ſo ſimilar, that the one may often be miſtaken for the other. Beſide the productions peculiar to theſe elements, as cryſtal, glaſs, &c. they give riſe to many great phænomena, which have ſuch ſtrong reſemblances, that they can hardly be diſtinguiſhed. Water, as we have ſeen, elevates mountains, and forms the greateſt number of iſlands: Some mountains and iſlands likewiſe derive their origin from fire. The ſame obſervation is applicable to caverns, fiſſures, gulfs, &c. Some of them are the effects of fire, and others of water.

Caverns are, in a great meaſure, peculiar to mountains: They are ſeldom or never found in plains. They are frequent in the Archipelago, and other iſlands; becauſe iſlands are generally nothing but the tops of mountains. Caverns, like precipices, are formed by the ſinking or mouldering of rocks, or, like abyſſes, by the action of fire; for, to make a cavern form a precipice or an abyſs, nothing farther is neceſſary than that the tops of the oppoſite rocks ſhould come together and form an arch, which muſt frequently happen when they are looſened at the root, and ſhaken by earthquakes, or by the operation of time and of the weather. Caverns

verns may be produced by the ſame cauſes which give riſe to gulfs, apertures, or ſinkings of the earth; and theſe cauſes are explosions of volcano's, the action of ſubterraneous vapours, and earthquakes, which create ſuch commotions in the earth, as muſt neceſſarily produce caverns, fiſſures, and hollows of every kind.

The cavern of St. Patrick in Ireland is not ſo conſiderable as it is famous: The ſame remark may be made with regard to the Grotto del Cane in Italy, and to that of Mount Beni-guazeval, in the kingdom of Fez, which throws out fire. There is a very large cavern in the county of Derby in England. It is much larger than the celebrated cavern of Bauman, near the Black Foreſt of Brunſwick. I was informed by the Earl of Morton, a philoſopher more reſpectable for his merit than his high rank, that the entrance to this cavern, called the *Devil's-hole*, is larger than the door of any church; that a ſmall river runs through it; that, after advancing ſome way, the vault of the cavern ſinks down ſo low, that, in order to proceed farther, it is neceſſary to lie flat in a boat, and to be puſhed through this narrow paſſage by people accuſtomed to the buſineſs; and that, after getting through, the roof, or arch of the cavern, riſes to a great height; and, after walking a conſiderable way on the ſide of the river, the arch ſinks again ſo low as to touch the ſurface of the water. Here the cavern terminates. The river,

 which

which ſeems to have its ſource in this part of the cavern, ſwells occaſionally, and tranſports heaps of ſand, which, by accumulating, forms a kind of blind alley, whoſe direction is different from that of the principal cavern.

In Carniola, near Potpechio, there is a large cavern, in which is a pretty conſiderable lake. Near Adelſperg, we meet with a cavern in which a man may travel two German miles. It contains ſeveral tremendous and deep precipices *. The Mendip hills in Somerſetſhire likewiſe preſent us with extenſive caverns, and very fine grottos. Near theſe caverns we find veins of lead, and ſometimes large oak-trees, buried 15 fathoms deep. In the county of Glouceſter, there is a large cavern called *Pen-park-hole*, at the bottom of which we meet with 32 fathoms of water. Here are alſo veins of lead.

It is apparent, that the Devil's-hole, and other caverns, from which large ſprings or brooks iſſue, have been gradually formed by the operation of the water, and their origin cannot be aſcribed to earthquakes or volcano's.

One of the largeſt and moſt ſingular caverns we are acquainted with, is that of Antiparos, of which M. Tournefort has given a complete deſcription. We firſt find a ruſtic cave about 30 feet wide, divided by ſome natural pillars. Between two pillars on the right, the ground ſlopes gently, and then more precipitately for about

* See Acta erud. Lipſ. anno 1689, p. 558.

20 pages

20 paces to the bottom of the cavern. This is the paſſage to the grotto or interior cave, and is nothing but a dark hole, through which a man cannot paſs without ſtooping, and the aſſiſtance of lights. We then deſcend, by means of a rope fixed at the entrance, a horrible precipice, and arrive on the borders of another ſtill more tremendous, with correſponding abyſſes on the left. By a ladder placed on the margin of theſe gulfs, we get over a vaſt perpendicular rock. We then continue to ſlip through places leſs dangerous. But, when we think ourſelves in the greateſt ſafety, we are ſuddenly ſtopped by a frightful paſs; to eſcape through which, we are obliged to glide on our backs along a large rock, and to deſcend by means of a ladder. When we arrive at the bottom of the ladder, we ſtumble for ſome time among irregular rocks, and then the famous grotto preſents itſelf. This grotto is about 300 fathoms below the ſurface of the earth, and it appears to be about 40 fathoms high, and 50 wide. It is full of large and beautiful ſtalactites, which both depend from the roof of the vault and cover the floor*.

In that part of Greece called Achaia by the ancients, now Livadia, there is a large cavern in a mountain which was formerly famous for the oracles of Trophonius: It is ſituated between the Lake of Livadia and the ſea, from which, at the neareſt part, it is diſtant about four miles; and

* See Tournefort's voyage to the Levant.

there are no leſs than 40 ſubterranneous paſſages through which the waters run under the mountain*.

In all countries which are ſubject to earthquakes or volcano's, caverns are frequent. The ſtructure of moſt of the iſlands of the Archipelago is exceedingly cavernous. The iſlands in the Indian Ocean, and particularly the Moluccas, appear to be chiefly ſupported upon vaults. The land of the Azores, of the Canaries, of the Cape de Verd iſlands, and, in general, of almoſt all ſmall iſlands, is, in many places, hollow and full of caverns; becauſe theſe iſlands, as formerly remarked, are only the tops of mountains, which have ſuffered great convulſions either from volcano's, or by the action of the waters, of froſts, and of other injuries of the weather. In the Cordelieres, where volcano's and earthquakes are frequent, there are many caverns, precipices, and abyſſes.

The famous labyrinth in the iſland of Crete is not the work of nature alone. We are aſſured by M. Tournefort, that, in many parts of it, the operation of men is evident; and, it is probable, that this is not the only cavern which has been augmented by art. Mines and quarries are conſtantly digging; and, after theſe have been long deſerted, it is not eaſy to determine whether ſuch excavations have been the effects of nature or of art. Some quarries are amazingly extenſive.

* See Gordon's Geography, p. 179.

five. That of Maeftricht, for inftance, is fufficient to fhelter 50,000 men, and is fupported by more than 1000 pillars of 20 feet high; and the earth and rock above is 25 fathoms thick*. The falt mines of Poland exhibit excavations ftill more extenfive. Near large cities, quarries and artificial hollows are common. But we muft proceed no farther in detail. Befides, the operations of men, however great, will always make but an inconfiderable figure in the hiftory of nature.

Volcano's and water, which form caverns in the bowels of the earth, produce likewife on its furface fiffures, precipices, and abyffes. At Cajeta in Italy, there is a mountain which had been formerly fplit by an earthquake in fuch a manner, that the feparation feems to have been made by the hands of men. We have already mentioned the *Wheel-track*, or great fiffure in the ifland of Machian, the abyfs of Mount Ararat, the port or gap in the Cordelieres, that of Thermopylæ, &c. To thefe we might add the gap in the mountain of the Troglodites in Arabia, and that of the *Ladders* in Savoy, which was begun by nature, and finifhed by Victor-Amadæus. Confiderable finkings in the earth, the fall of rocks, and the fubverfion of mountains, are frequently produced by the waters, as well as by fubterraneous fires. Of this many examples might be given.

* See Phil. Tranf. Abridg. vol. ii. p. 463.

'In the month of June 1714, a part of the 'mountain of Diablcret in Valois fell sudden-'ly, and, in a few hours, the sky being serene, 'it appeared to have assumed a conical figure. 'It destroyed 55 houses, besides several men, and 'a great many cattle; and it covered a league 'square with its ruins. The sky was darkened 'with the dust: The collection of stones and 'earth which were amassed on the plain, exceed-'ed 30 Rhenish perches in height, dammed up 'the waters, and gave rise to new lakes of con-'siderable depths. But this phænomenon was 'not accompanied with the least vestige of bitu-'men, sulphur, or calcined lime-stone; nor, con-'sequently, of subterraneous fire: The base of 'this great rock appeared to be rotten, and re-'duced to powder*.'

There is a remarkable example of these sink-ings near Folkstone in the county of Kent. The hills in the neighbourhood sunk insensibly, with-out any earthquake or other commotion. The interior parts of these hills consist of rocks and chalk; and, by their sinking, they have pushed part of the adjacent land into the sea. A well attested relation of this fact may be seen in the Philosophical Transactions †.

In 1618, the town of Pleurs was buried un-der the rocks at the foot of which it had been situated. In 1678, a great inundation was oc-

* Hist. de l'Acad. des Sciences, anneé 1715, p. 4.

† Abridg. vol. iv. p. 250.

casioned,

casioned, in Gascony, by the sinking of some portions of one of the Pyrennees, which forced out the water that had been pent up in the subterraneous caverns of these mountains. In the year 1680, a still greater inundation was produced in Ireland, by the sinking of a mountain into caverns which had been full of water. It is not difficult to investigate the cause of these effects. It is well known, that subterraneous waters are every where frequent. These waters gradually work away sand and earth in their passages; and, consequently, they may, in the course of time, destroy the stratum of earth which serves as a basis to the mountain: If this stratum fail more on one side than on another, the mountain must, of necessity, be overturned; or, if the base wastes gradually and equally throughout, the mountain will sink, without being overturned.

Having mentioned a few of those convulsions and changes produced in the earth by what may be called the accidents of nature, we must not pass over in silence the perpendicular fissures in the different strata. These fissures are obvious, not only in all rocks and quarries, but in clays, and in every species of earth which has never been removed from its natural position. They are called perpendicular fissures; because, like the horizontal strata, they are never oblique, but from some accidental change. Woodward and Ray talk of fissures, but in a general and confused

manner,

manner, and they never mention them under the appellation of perpendicular fiſſures, becauſe they imagined that they might be indifferently either oblique or perpendicular. No author has hitherto attempted to explain their origin, tho' it is apparent, as remarked in a former article, that they have been occaſioned by the drying of the materials which compoſe the horizontal ſtrata. In whatever manner this drying ſhould happen, perpendicular fiſſures muſt have been a neceſſary conſequence; for the matter of the horizontal ſtrata could not be diminiſhed in ſize, without ſplitting, at different diſtances, in a direction perpendicular to the ſtrata themſelves. Under perpendicular fiſſures, I comprehend, not only the natural cracks in rocks, but all thoſe ſeparations which have been effected by convulſive accidents. When a maſs of rock has ſuffered any conſiderable motion, the fiſſures are ſometimes placed obliquely; but it is becauſe the maſs itſelf is oblique; and the ſmalleſt attention to quarries of marble and lime-ſtone, or to great chains of rocks, will convince us, that the general direction of fiſſures is perpendicular to the ſtrata in which they are found.

The bowels of mountains are chiefly compoſed of parallel ſtrata of ſtones and rocks. Between the parallel ſtrata, we often meet with beds of matter ſofter than ſtone; and the perpendicular fiſſures are filled with ſand, cryſtals, metals, &c. The formation of theſe laſt bo-

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dies is more recent than that of the horizontal ſtrata in which ſea-ſhells are found. The rains have gradually detached the ſand and earth from the tops of mountains, and left the ſtones and rocks bare, which afford an opportunity of diſtinguiſhing with eaſe both the parallel ſtrata and the perpendicular fiſſures. On the other hand, the rains and rivers have ſucceſſively covered the plains with conſiderable quantities of earth, ſand, gravel, and other bodies which are either ſoluble in, or eaſily diviſible by water. Of theſe have been formed beds of tufa, of ſoft ſtone, of ſand, of rounded gravel, and of earth mixed with vegetable ſubſtances. But theſe beds contain no ſea-ſhells, or at moſt, but fragments of them, which have been detached from the mountains along with the earth and gravel. Theſe recent beds ſhould be carefully diſtinguiſhed from the ancient and original ſtrata, in which we almoſt univerſally find a greater number of entire ſhells placed in their natural ſituation.

In examining the internal order and diſtribution of the materials of a mountain, compoſed of common ſtone or calcinable lapidific matter, we generally find, after removing the vegetable ſoil, a bed of gravel, of the ſame nature and colour with the ſtones which predominate in the mountain; and, under the gravel, we meet with the ſolid rock. When the mountain is cut by a deep trench or *ravine*, the different banks or ſtrata are eaſily diſtinguiſhable. Each horizontal

tal ſtratum is ſeparated by a kind of joint or ſuture, which is likewiſe horizontal. Theſe ſtrata generally augment in thickneſs, in proportion to their depth or diſtance from the top of the mountain; and they are all divided, vertically, by perpendicular fiſſures. In general, the firſt ſtratum under the gravel, and even the ſecond, are not only thinner than thoſe which form the baſe of the mountain, but ſo much cut by perpendicular fiſſures, that ſmall portions of them only have any coherence. Moſt of theſe fiſſures, which exactly reſemble the cracks in earth that has been dried, gradually diſappear as they deſcend, and, at the baſe of the mountain, where they cut the larger ſtrata in a more regular and more perpendicular manner than thoſe near the ſurface, their number is much ſmaller.

Theſe ſtrata of rock often extend, without interruption, to great diſtances. Stones of the ſame ſpecies likewiſe are almoſt uniformly found in oppoſite mountains, whether they be ſeparated by a narrow neck or a valley; and the ſtrata never entirely diſappear, unleſs when the mountain terminates in a large and level plain. Sometimes we find, between the vegetable ſoil and the gravel, a ſtratum of marl, which communicates its colour, and other qualities, to the neighbouring beds: The perpendicular fiſſures in the inferior rocks are, in this caſe, filled with marl, where it acquires a hardneſs equal, in appearance, to that of the ſurrounding ſtone; but,

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when expoſed to the air, it ſplits, and becomes ſoft and ductile.

The beds of ſtone which compoſe the tops of mountains are generally ſoft and tender, but thoſe near the baſe are exceedingly hard. The firſt is commonly white, and of a grain ſo fine as to be hardly perceptible. In proportion as they deſcend, the rocks become more compact, and have a better grain; and the loweſt beds are not only harder than the ſuperior ones, but are alſo more compact and heavy. Their grain is fine and brilliant; and they are often ſo brittle as to break as purely and neatly as flint.

The heart of a mountain, then, is compoſed of different ſtrata of ſtones, which are harder or ſofter in proportion to their diſtance from the ſummit; and they are broad at the baſe, and ſharp and narrow at the top. The laſt is, indeed, a neceſſary reſult of the firſt: For, as the ſtones grow harder as they deſcend, it is natural to think, that the currents, and other motions of the water, which ſcooped out the valleys, and formed the contours of the mountains, muſt have gradually conſumed, by their lateral friction, the materials of which the mountains are compoſed; and that this conſumption would be proportioned to the hardneſs or ſoftneſs of the matter acted upon. But, as the upper ſtrata are known to be ſofteſt, and as their denſity increaſes according as they approach the baſe, the moun-

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tains muſt, of neceſſity, have aſſumed their preſent inclined, and ſomewhat conical figure. This is one great cauſe of the declivity of mountains; and it muſt always become more gentle, in proportion as the earth and gravel are brought down by the rain from their ſummits. For theſe reaſons, the declivity of hills and mountains, compoſed of calcinable bodies, is leſs than that of thoſe which conſiſt of granite, or of flint in large maſſes. The latter generally riſe almoſt perpendicularly to very great heights; becauſe in theſe maſſes of vitrifiable matter, the ſuperior, as well as the inferior ſtrata, are extremely hard, and have preſented nearly an equal reſiſtance to the operation of the waters.

Though, in the tops of ſome hills which are flat, and pretty extenſive, we find hard ſtone immediately under the vegetable ſoil; yet it ſhould be remarked, that, in every example of this kind, what appears to be the ſummit of a hill is only a continuation of ſome more elevated hill in the neighbourhood, the upper ſtrata of which conſiſt of ſoft, and the inferior ſtrata of hard ſtone; and the hard ſtone found on the top of the firſt hill is only a continuation of the under ſtrata of the higher hill.

Still, however, on the tops of hills which are not ſurmounted by higher grounds, the ſtone is moſtly of a ſoft and friable nature; and hard ſtone cannot be had without digging to a conſiderable depth. It is between theſe layers of

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hard ſtone only that marble is to be found; and it is variegated with different colours by metallic ſubſtances carried down by rain-water, and filtrated through the ſtrata: And it is probable that, in every country which furniſhes ſtones, marble would be found, if pits were dug to a ſufficient depth: *Quoto enim*, ſays Pliny, *loco non ſuum marmor invenitur?* It is, in fact, a more common ſtone than is generally imagined, and differs from other ſtones only in the fineneſs of its grain, which renders it compact, and ſuſceptible of a fine and brilliant poliſh.

Both the perpendicular fiſſures, and the horizontal joints of quarries, are often filled, or encruſted, with concretions, which are ſometimes tranſparent, and of regular figures, as cryſtals, and ſometimes earthy and opaque. Water runs through the perpendicular fiſſures, and even penetrates the cloſe texture of the ſtone itſelf. Stones which are porous imbibe water ſo copiouſly, that froſt ſplits them in pieces. The rain-waters, by filtrating through different ſtrata, are impregnated with a great variety of ſubſtances. They firſt ſink through the perpendicular fiſſures; they then penetrate the ſtrata of ſtone, and depoſite in the horizontal joints, as well as in the perpendicular fiſſures, ſuch matter as they collect in their courſe, and give riſe to different concretions, according to the nature of theſe ſubſtances. For example, when the water filtrates through marl, clay, or ſoft ſtone, the mat-

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ter which it depoſites is nothing but a fine pure marl, and commonly appears in the perpendicular fiſſures under the form of a porous, ſoft, white, light ſubſtance, known among naturaliſts under the name of *Lac Lunæ, or Medulla Saxi.*

When veins of water, charged with ſtony matter, run along the horizontal joints of ſoft ſtone or chalk, this matter adheres to the ſurface of the ſtones, and forms a white, ſcaly, light, and ſpongy cruſt, which, from its reſemblance to the agaric, has been called *mineral agaric.* But, if the ſtrata through which the water penetrates be hard ſtone, the filter being cloſer, the water it allows to paſs will be impregnated with a ſtony matter more pure and homogeneous; and, conſequently, the particles being capable of a more compact and intimate union, will form concretions, nearly of equal denſity with the ſtone itſelf, and ſomewhat tranſparent. In quarries of this kind, the ſurface of the ſtones are encruſted with undulated concretions, which entirely fill up the horizontal joints.

In grottos and cavities of rocks, which may be regarded as the baſins or common ſewers of the perpendicular fiſſures, the different directions of the veins of water give different forms to the concretions that reſult from them. Theſe forms are generally wreathed, or reſemble an inverted cone, attached to the roof of the cavern; or, rather, they are white, hollow cylinders, com-

poſed

poſed of concentric coats. The impregnated waters ſometimes fall in drops upon the floor of the cavern, and form columns, and a thouſand whimſical figures, to which naturaliſts have given the different appellations of *ſtalactites*, *ſtelegmites*, *oſteocollæ*, &c.

Laſtly, When the concreting juices iſſue immediately from marble, or very hard ſtone, the lapidific matter is rather diſſolved than ſuſpended in the water, and it forms a kind of columns with triangular points, which are tranſparent, and conſiſt of oblique coats. This ſubſtance is diſtinguiſhed by the name of *ſpar* or *ſpalt*. It is tranſparent and colourleſs, except when the ſtone or marble through which it filtrates contains metallic particles. This ſpar is of equal hardneſs with the ſtone itſelf, and it diſſolves in acids, and calcines with the ſame degree of heat. Hence it is evident, that ſpar is a true ſtone, and perfectly homogeneous. It may even be conſidered as a pure and elementary ſtone.

Moſt naturaliſts, however, conſider this as a diſtinct ſubſtance, exiſting independent of ſtone: It is the lapidific or cryſtalline juice, which, in their eſtimation, not only cements the particles of common ſtone, but even thoſe of flint. This juice, they allege, daily augments the denſity of ſtones by reiterated filtrations, and at laſt converts them into flint: When concreted into ſpar, it perpetually receives freſh ſupplies of ſtill purer juice, which increaſes both its hardneſs

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and its denſity, till it changes to the conſiſtence of glaſs, then to that of cryſtal, and at laſt it is converted into genuine diamond.

But, on this ſuppoſition, Why does the lapidific juice produce ſtone in ſome provinces only, and nothing but flint in others? It may be ſaid, that the one province is leſs ancient than the other, and that the juice has not had time ſufficient to complete its natural operations. But in this there is not the ſhadow of probability. Beſides, from whence does this juice proceed? If it gives riſe to ſtones and flints, from whence does it derive its own origin? It is obvious, that it has no exiſtence independent of thoſe ſubſtances which alone can impart to the water that penetrates them, a petrifying quality that uniformly correſponds with their nature and peculiar properties. Thus, when it filtrates through ſtone, it produces ſpar; when it iſſues from flint, it forms cryſtal; and there are as many ſpecies of this juice as of bodies from which it proceeds. Experience confirms this account of the matter. The waters, which filtrate through quarries of common ſtone, form tender and calcinable concretions ſimilar to the ſtones themſelves. On the other hand, the waters which exude from granite or from flint, produce concretions hard and vitrifiable, and they have all the other properties of flint, as the former had all thoſe of ſtone. In the ſame manner, the waters, which filtrate through mineral and metallic ſubſtances,

give riſe to pyrites, marcaſites, and metallic grains.

It was formerly remarked, that all matter might be divided into the two great claſſes of Vitrifiable and Calcinable. Clay and flint, marl and ſtone, may be regarded as the two extremes of each claſs, the intervals between which are filled with an almoſt infinite variety of mixts, that have always one or other of theſe ſubſtances for their baſis.

The ſubſtances belonging to the firſt claſs can never acquire the properties of thoſe of the latter. Stone, however ancient, will for ever be equally removed from the nature of flint, as clay is from that of marl. No known agent can ever force them from the circle of combinations peculiar to their nature. Places which produce marble and ſtone will always continue to do ſo, as infallibly as thoſe that produce only ſand-ſtone, flint, and granite, will never produce lime-ſtone or marble.

If we examine the order and diſtribution of the materials of a hill compoſed of vitrifiable ſubſtances, we ſhall generally find, under the vegetable ſoil, a ſtratum of clay, which is likewiſe a vitrifiable ſubſtance analogous to flint, and which, as already remarked, is only a decompoſition of vitrifiable ſand; or rather, we ſhall find, under the ſoil, a ſtratum of vitrifiable ſand. This ſtratum of clay or of ſand correſponds with the bed of gravel in hills conſiſting of calcinable matters.

matters. Below the ſtratum of clay or of ſand, we meet with ſome beds of free-ſtone, which ſeldom exceed half a foot in thickneſs, and they are divided into ſmall portions by perpendicular fiſſures. Under theſe are ſeveral ſtrata of the ſame matter, and likewiſe beds of vitrifiable ſand. In proportion as we deſcend, the free-ſtone is more denſe, and its thickneſs increaſes. Below theſe, we find what I call *live-rock*, or *flint in large maſſes*, a ſubſtance ſo hard as to reſiſt the file, and all kinds of acids, more powerfully than vitrifiable ſand or powder of glaſs, upon which aquafortis ſeems to have ſome effect. When ſtruck with another hard body, it throws out ſparks of fire, and exhales a penetrating ſulphureous vapour. This flinty ſubſtance is commonly found along with beds of clay, of ſlate, of pit-coal, of vitrifiable ſand; and it correſponds to the ſtrata of hard ſtone and marble, which ſerve as the baſes of hills that conſiſt of calcinable matter.

The waters, in paſſing through the perpendicular fiſſures, and in penetrating the ſtrata of vitrifiable ſand, of free-ſtone, of clay, and of ſlate, are impregnated with the fineſt and moſt homogeneous particles of theſe ſubſtances, and produce various concretions, ſuch as talc, aſbeſtos, and other bodies which owe their exiſtence to diſtillation through vitrifiable matter.

Flint, notwithſtanding its hardneſs and denſity, has, like marble and common ſtone, its exu-

tions,

dations, from which refult ftalactites of different fpecies, varying in tranfparency, colour, and configuration, according to the nature of the flint that produces them, and to the different metallic or heterogeneous particles it contains. Rock-cryftal, all the precious ftones, and even the diamond itfelf, may be regarded as ftalactites of this kind. The flints in fmall maffes, the ftrata or coats of which are generally concentric, are only ftalactites or parafitical ftones from the flints in large maffes; and moft of the fine opaque ftones are nothing but fpecies of flint. The fubftances produced by the vitrifiable clafs of bodies are not, as we have feen, fo various as the concretions formed by thofe of the calcinable. Moft of the concretions formed by flint are hard and precious ftones; but thofe produced by calcareous ftones are friable, and of no value.

Perpendicular fiffures are found in flint-rocks as well as in ftone. They are even frequently larger in flint, which proves this fubftance to be drier than ftone. Both the hill confifting of calcinable, and that compofed of vitrifiable matter, have clay or vitrifiable fand for their bafes, which are the moft commonly diffufed matters of the globe, and which I regard as the lighteft, being the fcoriæ of the vitrified matter that conftitutes the interior parts of the earth. Thus all mountains as well as plains are founded either on clay or fand. We have feen, for example, in the pits of Amfterdam, and in that of Marly-

la-ville, that vitrifiable ſand was always the deepeſt ſtratum.

It may be obſerved, in moſt bare rocks, that the walls of perpendicular fiſſures, whether they be narrow or wide, correſpond as exactly with each other as ſplit pieces of wood. In the large quarries of Arabia, which conſiſt moſtly of granite, the perpendicular fiſſures are frequent; and, though ſome of them are 20 or 30 yards wide, the ſides correſpond exactly, and leave a deep cavity between them*. It is likewiſe common to find, in perpendicular fiſſures, ſhells divided into two pieces, each piece remaining attached to the oppoſite ſides of the fiſſure; which proves, that theſe ſhells were depoſited in the ſolid ſtratum before it was ſplit †.

In ſome quarries mentioned by Mr. Shaw, the perpendicular fiſſures are exceedingly large; and for this reaſon, perhaps, they are leſs numerous. In quarries of granite and flint in large maſſes, blocks of ſtone may be raiſed, as the obeliſks and columns at Rome, of 60, 80, 100, and 150 feet long, without the leaſt interruption. It appears, that theſe vaſt blocks have been raiſed from the ſame quarry, and, like ſome ſpecies of free-ſtone, that they may be had of any given thickneſs. In other ſubſtances, the perpendicular fiſſures are very narrow, as in clay, in marl, and in chalk; and they are wider in

* See Shaw's Travels. † See Woodward, p. 298

marble and hard ſtone. Some are imperceptible, becauſe they have been filled with a matter nearly ſimilar to that of the ſtone itſelf; but ſtill they interrupt the continuity of the ſtones, and are called *hairs* by the workmen. I have often remarked, that theſe hairs in marble and ſtone differed from perpendicular fiſſures only in the ſeparation of parts not being complete. Theſe ſpecies of fiſſures are filled with a tranſparent matter, which is a true ſpar. In quarries of free-ſtone, the fiſſures are numerous, and conſiderably large, becauſe rocks of this kind have often a leſs ſolid baſe than that which ſupports marble or lime-ſtone, the former generally reſting upon a fine ſand, and the latter upon clay. In many places, free-ſtone is not to be found in large maſſes; and in moſt quarries, where this ſtone is good, the blocks lie irregularly upon one another, in the form of cubes or parallelopipeds, as in the hills of Fountainbleau, which appear, at a diſtance, like the ruins of old buildings. This irregular diſpoſition has been occaſioned by the ſandy foundation of theſe hills allowing the blocks to ſink and tumble upon each other, eſpecially where quarries have been formerly wrought, which has given riſe to a great variety of fiſſures and intervals between the different blocks: And it may be remarked, in all countries abounding with ſand and free-ſtone, that there are many fragments of rocks and large ſtones in the middle of the plains and valleys;

and that, on the contrary, in countries abounding with marble and hard ſtone, theſe ſcattered fragments, which have rolled down from the hills, are exceedingly rare. This phænomenon is owing to the different ſolidities of the baſes upon which theſe ſtones are ſupported, and to the extent of the banks of marble or lime-ſtone, which is always more conſiderable than that of free-ſtone.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XVIII.

Of the Effects of Rains—Of Marshes, Subterraneous Wood and Waters.

IT has already been remarked, that rains, and the currents of water which they produce, continually detach, from the summits and sides of mountains, earth, gravel, &c. and carry them down to the plains; and that the rivers transport part of them to the sea. The plains, therefore, by fresh accumulations of matter, are perpetually rising higher; and the mountains, for the same reason, are constantly diminishing both in size and elevation. Of the sinking of mountains, Joseph Blancanus relates several facts which were publicly known in his time. The steeple of the village of Craich, in the county of Derby, was not visible in 1572, from

from a certain mountain, on account of a higher mountain which intervened; but 80 or 100 years afterwards, not only the ſteeple, but likewiſe part of the church, were viſible from the ſame ſtation. Dr. Plot gives a ſimilar example of a mountain between Sibbertoft and Aſhby, in the county of Northampton. Sand, earth, gravel, and ſmall ſtones, are not only carried down by the rains, but they ſometimes undermine and drive before them large rocks, which conſiderably diminiſh the height of mountains. In general, the rocks are pointed and perpendicular in proportion to the height and ſteepneſs of mountains. The rocks in high mountains are very ſtraight and naked. The large fragments which appear in the valleys have been detached by the operation of water and of froſts. Thus ſand and earth are not the only ſubſtances detached from mountains by the rains; they attack the hardeſt rocks, and carry down large fragments of them into the plains. At Nant-phrancon, in 1685, a part of a large rock, which was ſupported on a narrow baſe, being undermined by the waters, fell and ſplit into a number of fragments, the largeſt of which made deep trenches in the plain, croſſed a ſmall river, and ſtopped on the other ſide. To ſimilar accidents we muſt aſcribe the origin of all thoſe large ſtones which are found in valleys adjacent to mountains. This phænomenon, as formerly remarked, is more common in countries where the

mountains.

mountains are composed of sand and free-stone, than in those the mountains of which consist of clay and marble; because sand is a less solid basis than clay.

To give an idea of the quantity of earth detached from mountains by the rains, we shall quote a passage on this subject from Dr. Plot's natural history of Stafford. He remarks, that a great number of coins struck in the reign of Edward IV. *i. e.* 200 years ago, were found buried 18 feet below the surface: Hence, he concludes, that the earth, which is marshy where the coins were found, augments about a foot in eleven years, or an inch and a twelfth each year. A similar observation may be made on trees buried 17 feet below the surface, under which were found medals of Julius Cæsar. Thus, the soil of the plains is considerably augmented and elevated by the matters washed down from the mountains.

The sand, gravel, and earth carried down from the mountains into the plains, form beds which ought not to be confounded with the original strata of the globe. To the former belong the beds of tufa, of soft stone, and of sand and gravel which have been rounded by the operation of water. To these may be added those beds of stone which have been formed by a species of incrustation, none of which derive their origin from the motion or sediments of the sea. In these strata of tufa and of soft imperfect stones,

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we find a number of different vegetables, leaves of trees, land or river-ſhells, and ſmall terreſtrial animals, but never ſea-ſhells, or other productions of the ocean. This circumſtance, joined to their want of ſolidity, evidently proves, that theſe ſtrata have been ſuperinduced upon the dry ſurface of the earth, and that they are more recent than thoſe of marble and other ſtones, which contain ſea-ſhells, and have been originally formed by the waters of the ſea. Tufa, and other new ſtones, appear to be hard and ſolid when firſt dug out of the earth; but they ſoon diſſolve after being expoſed to the operation of the weather. Their ſubſtance is ſo different from that of true ſtone, that, when broken down in order to make ſand of them, they change into a kind of dirty earth. The ſtalactites, and other ſtony concretions which Mr. Tournefort apprehended to be marbles that had vegetated, are not genuine ſtones. We have already ſhown, that the formation of tufa is not ancient; and that it is not entitled to be ranked with ſtones. Tufa is an imperfect ſubſtance, differing from ſtone or earth, but deriving its origin from both by the intervention of rain water, in the ſame manner as incruſtations are formed by the waters of certain ſprings. Thus, the ſtrata of theſe ſubſtances are not ancient; nor have they, like the other ſpecies, been formed by ſediments from the waters of the ocean. The ſtrata of turf are alſo recent and have been produced by ſucceſſive accumula-

tions

tions of half corrupted trees and other vegetables, which owe their preſervation to a bituminous earth. No production of the ſea ever appears in any of theſe new ſtrata. But, on the contrary, we find in them many vegetables, the bones of land-animals, and land and river-ſhells. In the meadows near Aſhly, in the county of Northampton, for example, they find, ſeveral feet below the ſurface, ſnail-ſhells, plants, herbs, and ſeveral ſpecies of river-ſhells, well preſerved; but not a ſingle ſea-ſhell appears*. All theſe new ſtrata have been formed by the waters on the ſurface changing their channels, and diffuſing themſelves on all ſides. Part of theſe waters penetrate the earth, and run along the fiſſures of rocks and ſtones. The reaſon why water is ſo ſeldom found in high countries, or on the tops of hills, is, becauſe high grounds are generally compoſed of ſtones and rocks. To find water, therefore, we muſt cut through the rocks till we arrive at clay or firm earth. But, when the thickneſs of the rock is great, as in high mountains where the rocks are often 1000 feet high, it is impoſſible to pierce them to their baſe; and conſequently it is impoſſible to find water in ſuch ſituations. There are even extenſive countries that afford no water, as in Arabia Petrea, which is a deſert where no rains fall, where the ſurface of the earth is covered with burning ſands, where there is hardly the appearance of any ſoil, and where nothing but a few ſickly plants are pro-

* See Phil. Tranſ. Abridg. vol. iv. p. 271.

duced.

duced. In this miserable country, wells are so rare, that travellers enumerate only five between Cairo and Mount Sinai, and the water they contain is bitter and saltish.

When the superficial waters can find no outlets or channels, they form marshes and fens. The most celebrated fens in Europe are those of Russia at the source of the Tanais; and those of Savolaxia and Enasak in Finland: There are also considerable marshes in Holland, Westphalia, and other countries. In Asia are the marshes of the Euphrates, of Tartary, and of the Palus Meotis. However, marshes are less frequent in Asia and Africa than in Europe. But the whole plains of America may be regarded as one continued marsh; which is a greater proof of the modernness of this country, and of the scarcity of its inhabitants, than of their want of industry.

There are extensive fens in England, particularly in Lincolnshire, near the sea, which has lost a great quantity of land on one side, and gained as much on the other. In the ancient soil many trees are found buried under the new earth which has been transported and deposited by the water: The same phænomenon is common in the marshes of Scotland. Near Bruges in Flanders, in digging to the depth of 40 or 50 feet, a vast number of trees were found, as close to each other as they are in a forest. Their trunks, branches, and leaves were so well preserved, that their different species could be easily distinguished.

diſtinguiſhed. About 500 years ago, the earth where theſe trees were found was covered with the ſea; and, before this time, we have neither record nor tradition of its exiſtence. It muſt, however, have been dry-land when the trees grew upon it. Thus the land, that, in ſome remote period, was firm, and covered with wood, has been overwhelmed with the waters of the ſea, which, in the courſe of time, have depoſited 40 or 50 feet of earth upon the ancient ſurface, and then retired. A number of ſubterraneous trees was likewiſe diſcovered at Youle in Yorkſhire, near the river Humber. Some of them are ſo large as to be of uſe in building; and it is affirmed, that they are as durable as oak. The country-people cut them into long thin ſlices, and ſell them in the neighbouring villages, where the inhabitants employ them for lighting their pipes. All theſe trees appear to be broken; and the trunks are ſeparated from the roots, as if they had been thrown down by a hurricane or an inundation. The wood appears to be fir; it has the ſame ſmell when burnt, and makes the ſame kind of charcoal*. In the Iſle of Man, there is a marſh called *Curragh*, about ſix miles long and three broad, where ſubterraneous fir-trees are found; and, though 18 or 20 feet below the ſurface, they ſtand firm on their roots†. Theſe trees are common in the marſhes and bogs

* See Phil. Tranſ. No. 228.

† See Ray's Diſcourſes, p. 232.

of Somerfet, Chefter, Lancafhire, and Stafford. In fome places there are fubterraneous trees which have been cut, fawed, and fquared by the hands of men; and even axes, and other implements are often found near them. Between Birmingham and Bromley, in the county of Lincoln, there are hills of a fine light fand, which is blown about by the winds, and tranfported by the rains, leaving bare the roots of large firs, in which the impreffions of the ax are ftill exceedingly apparent. Thefe hills have unqueftionably been formed, like downs, by fucceffive accumulations of fand tranfported by the motions of the fea. Subterraneous trees are alfo frequent in the marfhes of Holland, Friefland, and near Groningen, which abound in turfs.

Subterraneous trees are of different fpecies, viz. firs, oaks, birch, beech, yew, hawthorn, willow, afh, &c. In the fens of Lincoln, along the river Oufe, and on Hatfield-chace in Yorkfhire, thefe trees ftand erect, as if they were growing in a foreft. The oaks are extremely hard, and are ufed in building, where they are faid to laft long, which I think improbable, as all the fpecimens I have examined lofe their folidity, after being dried and expofed to the air. The afhes are tender, and foon fall into duft. Some of thefe trees are evidently cut and fawed with inftruments; and the hatchets, which are fometimes found along with them, refemble the knives formerly ufed in facrifices. Befide trees, we

we alſo meet with vaſt quantities of filberds, acorns, and fir-cones, in many other fens in England, Scotland, and Ireland, as well as in the marſhes of France, Switzerland, Savoy, and Italy*.

For four miles round the town of Modena, whenever the earth is dug to the depth of 63 feet, the workmen pierce about five feet more with a boring inſtrument, through which the water ruſhes up with ſuch impetuoſity, that it fills the wells to the top, almoſt inſtantaneouſly. The water in theſe wells continues perpetually, and is neither augmented nor diminiſhed by rains or drought. What is ſtill more remarkable in this ſpot, whenever the workmen dig to the depth of 14 feet, they find the rubbiſh and ruins of an ancient city, paved ſtreets, houſes, and different pieces of Moſaic work. Below this, the earth is ſolid, and appears not to have been moved. Still lower, however, we find a moiſt ſoil mixed with vegetables; and, at the depth of 26 feet, entire trees, as filberds, with nuts upon them, and great quantities of branches and leaves. At 28 feet, there is a ſtratum of ſoft chalk, 11 feet thick, mixed with ſea-ſhells; and after this we ſtill meet with vegetables, leaves and branches of trees, till we arrive at the depth of 63 feet, where there is a ſtratum of ſand mixed with gravel and ſhells, ſimilar to thoſe which appear on the coaſts of Italy. Theſe

* See Phil. Tranſ. Abridg. vol. iv. p. 218, &c.

fucceffive ftrata lie always in the fame order, wherever pits have been dug; and fometimes the boring inftrument falls in with the trunks of large trees, which the workmen pierce with great labour: They likewife meet with bones of animals, pit-coal, flints, and pieces of iron. Ramazzini, who relates thefe facts, thinks, that the gulf of Venice formerly extended beyond Modena, and that this land, in the progrefs of time, has been gradually formed by the rivers, affifted, perhaps, by inundations of the fea.

I will infift no longer upon the varieties in the compofition of new ftrata. It is fufficient to have fhown that they have been produced by no other caufe than the waters which run or are ftagnant upon the furface, and that they are neither fo hard nor fo folid as the ancient ftrata which were formed under the waters of the ocean.

PROOFS

OF THE

THEORY OF THE EARTH.

ARTICLE XIX.

Of the Changes of Land into Sea, and of Sea into Land.

FROM what has been remarked in article 1. 7. 8. and 9. it is apparent, that the terreſtrial globe has undergone ſome great and general changes; and it is equally certain, from what has been delivered in the other articles, that the ſurface of the earth has ſuffered particular alterations: Though we are not ſufficiently acquainted with the order or ſucceſſion of theſe particular changes, we know the principal cauſes by which they were produced. We can even diſtinguiſh their different effects; and, if we were able to collect all the facts which natural and civil hiſtory afford concerning the revolu-

 tions

tions that have happened on the ſurface of the earth, our theory would unqueſtionably receive additional ſupports, and would be rendered ſtill more ſatisfactory.

One of the principal cauſes of theſe revolutions is the motion of the ſea, which has continued invariably the ſame in all ages; for, as the ſun, the moon, the earth, the waters, the air, &c. have exiſted from the moment of creation, the effects of the tides, of the motion of the ſea from eaſt to weſt, of the currents, and of the winds, muſt have been felt for an equal time: And, even ſuppoſing the axis of the globe to have formerly had a different inclination, and that the continents, as well as the ſeas, were differently diſpoſed, the motions of the ocean, and the cauſes and effects of the winds, would have remained unaltered. In whatever part of the globe the immenſe quantities of water which fill the ocean were collected, they would be ſubject to the ſame motions.

It was no ſooner ſuſpected that our continent might formerly have been the bottom of the ſea, than the fact became inconteſtible. The ſpoils of the ocean found in every place, the horizontal poſition of the ſtrata, and the correſponding angles of the hills and mountains, appeared to be convincing proofs; for, when we examine the plains, the valleys, and the hills, it is apparent, that the ſurface of the earth has been figured by the waters. When we deſcend into the

the bowels of the earth, it is equally evident, that thoſe ſtones which include ſea-ſhells, have been formed by ſediments depoſited by the waters, ſince the ſea-ſhells themſelves are impregnated with the ſame matter that ſurrounds them. And, in fine, if we conſider the correſponding angles of the hills and mountains, we cannot heſitate in pronouncing, that they received their configuration and direction from currents of the ocean. It is true, that, ſince the earth was firſt left uncovered with water, the original figure of its ſurface has been gradually changing: The mountains have diminiſhed in height; the plains have been elevated; the angles of the hills have become more obtuſe; thoſe bodies which have been rolled along by the rivers have received a roundiſh figure; new beds of tufa, of ſoft ſtone, of gravel, &c. have been formed. But every thing has remained eſſentially the ſame. The ancient form is ſtill recogniſable; and I am perſuaded, that every man may be convinced, by his own eyes, of the truth of all that has been advanced on this ſubject; and, that whoever has attended to the proofs I have given, muſt be fully ſatisfied, that the earth was formerly under the waters of the ocean, and that the ſurface which we now behold, received its configuration from the currents and movements of the ſea.

We formerly remarked, that the principal motion of the ſea is from eaſt to weſt. The ocean, accordingly, ſeems to have gained from

the eaſtern coaſts both of the Old and the New Continent, a ſpace of no leſs than 500 leagues. For the proofs, we muſt refer to Art. IX. and ſhall here only add, that the direction of all ſtraits which join two ſeas, is from eaſt to weſt. The ſtraits of Magellan, of Frobiſher, of Hudſon, of Ceylon, of the ſea of Corea, and of Kamtſchatka, lie all in this direction, and appear to have been formed by the irruption of the waters, which, being forcibly puſhed from eaſt to weſt, have opened theſe paſſages, where the waters ſtill preſerve a ſtronger current in this than in any other direction; for, in all ſtraits of this kind, the tides are high and violent; but, in thoſe ſituated on the weſtern coaſts, as that of Gibraltar, of Sunda, &c. the motion of the tides is almoſt imperceptible.

The inequalities at the bottom of the ſea change the direction of the motion of the waters. Theſe inequalities have originated from ſediments and matters tranſported by the tides, or by other movements in the water: The tides are the principal and firſt, though not the only cauſe, which produced theſe inequalities. The wind is another cauſe; though its action begins at the ſurface, it agitates the whole maſs to the greateſt depths, as appears from particular bodies which are detached from the bottom of the ſea, and thrown aſhore during violent ſtorms only.

It

It has already been mentioned, that, between the Tropics, and even ſome degrees beyond them, an eaſt wind perpetually blows. This wind, which aſſiſts the general motion of the ſea from eaſt to weſt, is as ancient as the tides; becauſe it is occaſioned by the rarefaction of the air produced by the heat of the ſun. There are two combined cauſes, therefore, the operation of which is greateſt in the equatorial regions: *1ſt*, The tides, which are greateſt in the ſouthern latitudes; and, *2d*, The eaſt winds, which conſtantly reign in theſe climates. Theſe two cauſes have concurred, from the firſt formation of the earth, in producing a motion in the waters from eaſt to weſt, and in agitating them more violently in this region of the globe than in any other. It is for this reaſon that we find between the Tropics the greateſt inequalities upon the ſurface of the earth. That part of Africa which lies between theſe circles, is nothing but a group of different chains of mountains, which generally extend from eaſt to weſt, as appears from the direction of the great rivers that traverſe this unknown region. The ſame obſervation holds with regard to the countries both of Aſia and America, which lie between the Tropics.

The general motion of the ſea from eaſt to weſt, combined with the tides, currents, and winds, produce a variety of effects, both on the bottom of the ocean, and on the coaſts. Vare-

nius thinks it extremely probable, that gulfs and ftraits have been formed by reiterated efforts of the ocean againft the land; that the gulfs of Arabia, of Bengal, and of Cambaya, have been produced by irruptions of the waters, as well as the ftraits between Sicily and Italy, between Ceylon and India, between Greece and Eubœa, &c.; that the probability of fuch irruptions, and of certain lands having been deferted by the fea, is ftrengthened by the fcarcity of iflands in the middle of great feas, and by their never appearing there in groups; that, in the immenfe fpace occupied by the Pacific Ocean, there are only two or three fmall iflands near the centre of it; and that, in the vaft Atlantic Ocean between Africa and Brafil, we find only the fmall iflands of St. Helena and Afcenfion: But all iflands lie near large continents, as thofe of the Archipelago, which approach the continents both of Europe and Afia; the Canaries are near Africa; the Indian iflands lie near the eaftern part of the continent of Afia; the Antilles lie off the coaft of America; and the Azores alone lie at a confiderable diftance both from Africa and America.

The popular tradition among the inhabitants of Ceylon, that their ifland had been feparated from the peninfula of India by an irruption of the fea, is extremely probable. The great number of rocks and fhoals between the ifland of Sumatra and the continent demonftrate their former

former union. The Malabarians affirm, that the Maldiva iflands once made a part of the continent of India; and, in general, we may believe, without hefitation, that all the eaftern iflands have been feparated from continents by irruptions of the ocean *.

The ifland of Great Britain appears to have been formerly a part of the continent; and that England was once joined to France, the narrownefs of the ftrait, and the famenefs of the ftrata of ftone and of earth on the oppofite fides, are a fufficient indication. If we fuppofe, fays Dr. Wallis, that France was connected to England by an ifthmus between Calais and Dover, two tides would neceffarily ftrike with violence againft each fide of it twice every twenty-four hours; and the operation of the fea, both on the eaft and weft of this ifthmus, would, in the courfe of time, gradually cut through fuch a narrow neck of land. The tides acting with violence not only againft this ifthmus, but alfo againft the coafts of France and of England, muft have carried away vaft quantities of earth, fand, and clay, from every part on which the waves exerted their fury. Their courfe, however, being interrupted by the ifthmus, they would not, as might be imagined, depofite their fediments upon its fhores, but would tranfport and depofite them on the great plain which now

* See Varen. Geogr. p. 203. 217. and 220.

forms

forms the marſh of Romney, and is four miles broad and eight long; for no man, who has ever ſeen this plain, can poſſibly doubt of its having been formerly covered with the ſea, as, without the intervention of the dikes of Dimchurch, a great part of it would ſtill be overflowed by the ſpring-tides.

The German ſea would act in the ſame manner againſt this iſthmus and againſt the coaſts of England and Flanders, and would carry its ſediments into Holland and Zeland, the ſoil of which was formerly under the waters, though it is now elevated 40 feet above them. On the Engliſh coaſt, the German ſea muſt have occupied that large valley which commences at Sandwich, runs by Canterbury, Chatham, Chilham, and terminates at Aſhford, a ſpace of more than 20 miles. Here the land is much more elevated than it was in ancient times; for, at Chatham, the bones of an hyppopotamos were found buried at the depth of 17 feet, and likewiſe anchors of ſhips, and ſea-ſhells.

Nothing is more apparent than that new lands are formed by the earth, ſand, clay, &c. tranſported and depoſited by the ſea: For, in the iſland of Okney, which is adjacent to the marſhy coaſt of Romney, there was a flat ſpace of ground in continual danger of being overflowed by the river Rother; but this flat, in leſs than 60 years, has been conſiderably elevated by the acceſſion of

of fresh matter brought in by every tide. This river has, besides, deepened its channel so much, that its mouth, which, less than 50 years ago, was fordable by men, is now capable of receiving large vessels.

In the same manner has the bank of sand, which runs obliquely from the coast of Norfolk to that of Zeland, been formed. This bank is the place where the German and French seas encounter since the rupture of the isthmus; and it is here that the waters deposite the earth and sand which they carry off from the coasts. It is even probable that this bank of sand may, in a succession of ages, give rise to a new isthmus*.

It is extremely probable, says Mr. Ray, that the island of Great Britain was formerly joined to France: Whether it was separated by an earthquake, by an irruption of the ocean, or by the operation of men, we know not. But the former junction of Britain to the continent is apparent from the identity of the rocks and different strata, at the same elevation, on the opposite coasts; and from the similar extent of the rocks on each side, being both about six miles. The narrowness of this strait, which exceeds not 24 English miles, and its shallowness, when compared to the depth of the neighbouring sea, render it probable that England has been separated from France by some accident. To these proofs

* See Phil. Transf. Abridg. vol. iv. p. 227.

we might add, that wolves and bears formerly exiſted in this iſland: It is not probable that theſe animals could ſwim over, nor that ſuch deſtructive creatures would be tranſported by men; for, in general, the noxious animals of the continent are found in all thoſe iſlands which are very near it, but never in thoſe that are remote. This fact was remarked by the Spaniards when they arrived at America *.

In the reign of Henry I. of England, a part of Flanders was overflowed by an irruption of the ſea. In 1446, more than 10,000 perſons were drowned by a ſimilar irruption in the territory of Dordrecht, and more than 100,000 round Dullart in Friſeland and Zeland. In theſe two provinces, above 300 villages were overflowed. The tops of their towers and ſpires are ſtill viſible above the ſurface of the water.

From the coaſts of France, England, Holland, and Germany, the ſea has in many places retreated. Hubert Thomas, in his deſcription of the country of Liege, aſſures us, that the walls of the city of Tongres were formerly ſurrounded by the ſea, though it is now 35 leagues diſtant from that city. He gives ſeveral ſatisfactory reaſons: Among others, he informs us, that, in his time, the iron rings, to which ſhips were faſtened, ſtill remained in the walls. The fens of Lincoln, of the iſland of Ely, and the Crau of Provence in France, may be regarded as

* See Ray's Diſcourſes, p. 208.

lands

lands abandoned by the ſea, which has likewiſe, ſince the year 1665, retired conſiderably from the mouth of the Rhone. At the mouth of the Arno in Italy, a large quantity of land has been gained from the ſea; and Ravenna, which was formerly a harbour, is no longer a ſea-port. The whole of Holland appears to be new land: The ſurface of the ground is nearly on a level with the ſea, although it has received daily elevations from the mud and earths tranſported by the Rhine, the Maeſe, &c.; for the ſoil of Holland was formerly, in many places, computed to be 50 feet below the level of the ſea.

It has been alledged, that, in the year 860, a furious tempeſt drove ſuch quantities of ſand upon the coaſt, that the mouth of the Rhine near Catt was entirely blocked up; and that this river overflowed the whole country, overturned trees and houſes, and at laſt emptied itſelf into the channel of the Maeſe. In 1421, another inundation ſeparated the city of Dordrecht from the main land, overwhelmed 72 villages, and drowned 100,000 perſons, beſide a vaſt number of cattle. The dike of Iſſel was broken down in 1638, by the ice-boards from the Rhine blocking up the paſſage of the water, which occaſioned an opening in the dike of ſeveral fathoms; and a great part of the province was laid under water before the breach could be repaired. The province of Zeland, in 1682, ſuffered a ſimilar inundation, which drowned more than 30 villages; and an

amazing

amazing number of men and cattle perifhed, as the unfortunate event happened during the night. The lofs would have been ftill greater, had not a fouth-eaft wind oppofed the motion of the waves; for there was fuch a fwell in the fea, that the water rofe 18 feet above the higheft ground in the province*.

The harbour of Hithe, in the county of Kent, is entirely blocked up, notwithftanding much labour and expence beftowed, on different occafions, to clear it from rubbifh. For feveral miles round, we find an aftonifhing quantity of fhells and other fea-bodies, which had been accumulated in ancient times, and which are now covered with foil, and afford excellent pafturage. The fea, on the other hand, often encroaches upon the land. The lands of Goodwin, for example, which formerly belonged to a Nobleman of that name, are now converted into fands, and are covered with the waters of the ocean. Thus the fea gains upon fome coafts, and lofes upon others, according to their different fituations and circumftances †.

Upon Mount Stella, in Portugal, there is a lake, in which are found the wrecks of fhips, though this mountain is 12 leagues diftant from the fea ‡. Sabinius, in his commentary upon Ovid's Metamorphofes, tells us, that, in the year

* See les Voyag. hift. de l'Europe, tom. v. p. 70.

† See Phil. Tranf. Abridg. vol. iv. p. 234.

‡ See Gordon's Geog. Gram. p. 149.

1460,

1460, a ſhip, with its anchors, were found in one of the Alpine mines.

Theſe changes of ſea into land, and of land into ſea, are not peculiar to Europe. The other parts of the globe, if properly inveſtigated, would furniſh more ſtriking and numerous examples.

Calecut was formerly a celebrated city, and the capital of a kingdom of that name. It is now reduced to an inconſiderable town, ill-built, and almoſt deſerted. The ſea, which, for a century paſt, has gained greatly upon this coaſt, now covers moſt of the ancient city. Ships moor upon its ruins, and the port is choaked up with a number of rocks, upon which many veſſels have been wrecked*.

The province of Jucatan, a peninſula in the Gulf of Mexico, was formerly a part of the ſea. This neck of land ſtretches about 100 leagues in length, and is no where above 25 leagues broad. The air is hot and moiſt. The earth furniſhes plenty of water, though, in ſo large a country, there are neither rivers nor brooks; and, when pits are dug, ſuch multitudes of ſhells every where appear, as leave no room for doubting that this whole tract of land was formerly a part of the ocean.

It is a tradition among the inhabitants of Malabar, that the Maldiva iſlands originally belonged to the continent of India, and that they were detached from it by the violence of the ocean.

* See Lettres Edifiantes, recueil ii. p. 187.

The

The number of theſe iſlands is ſo great, and they are ſeparated by ſuch narrow channels, that the bow-ſprits of veſſels in paſſing, drive off leaves from the trees on each ſide; and, in ſome places, a vigorous man, by laying hold of a branch, may leap into another iſland *. The cocoa trees found at the bottom of the ſea, is a farther proof that the Maldivas formerly belonged to the continent.

The iſland of Ceylon, thoſe of Rammanakoiel, and many other iſlands, it is believed, were alſo disjoined from the continent by currents, which, in many places of the Indian ſea, are extremely rapid †. It is certain, however, that the ſea has encroached 30 or 40 leagues on the north-eaſt coaſt of Ceylon.

The ſea appears to have lately abandoned many of the promontories and iſlands of America. We have already remarked that the territory of Jucatan is full of ſhells. The ſame phænomenon takes place in the low grounds of Martinico and the other Antilles. The inhabitants diſtinguiſh the earth below the ſurface by the name of *lime*; becauſe they make lime of the ſhells, great banks of which lie immediately under the vegetable ſoil ‡.

There are ſome lands which the ſea alternately covers and leaves bare, as happens in ſeveral iſlands

* See Voyages des Hollandois aux Indes Orientales, p. 274.
† Ibid. vol. iv. p. 485.
‡ See Nouv. Voyages aux Iſles de l'Amerique.

of

Norway, Scotland, the Maldiva's, the gulf of Cambaya, &c. The Baltic ſea has gradually gained a great part of Pomerania; and it has covered and deſtroyed the celebrated port of Vineta. In the ſame manner, the Norwegian ſea has advanced into the continent, and formed ſeveral iſlands. The German ſea has encroached upon Holland, near Catt, to ſuch a degree, that the ruins of an ancient Roman citadel, which was formerly ſituated on the coaſt, lie now at a conſiderable diſtance in the ſea. The marſhy ground in the iſland of Ely, and the Crau of Province, are, on the contrary, lands which the ſea has deſerted. The Downs have been formed by accumulations of ſand, earth, and ſhells ſucceſſively driven upon the coaſts by winds blowing from the ſea. For example, on the weſt coaſts of France, Spain, and Africa, a violent weſt wind reigns, by which the waters are puſhed with violence againſt the ſhores; and downs, accordingly, are frequent on theſe coaſts. The eaſt winds, in the ſame manner, when they continue long, drive the waters ſo forcibly from the coaſts of Syria and Phœnicia, that large chains of rocks, which are covered during the weſt winds, are left dry. Beſides, downs are not compoſed of ſtones and marble, like the mountains which have been formed in the bottom of the ocean, becauſe they have not remained long enough under the waters. That the waters of the ſea poſſeſs a petrifying power, and that

the ſtones formed in the earth are very different from thoſe formed at the bottom of the ocean, is fully evinced in my diſcourſe on minerals.

Since finiſhing my theory of the earth, which was compoſed in the year 1744, I have peruſed M. Barrere's diſſertation on the origin of figured ſtones. It gave me peculiar ſatisfaction to find that the ideas of this accompliſhed naturaliſt, concerning the formation of downs, and the duration of the ſea upon the ſurface of the earth which we inhabit, exactly correſponded with my own. Aiguis-mortes, which is now more than a league and a half from the ſea, was a port in the time of St. Louis. Pſalmodi was an iſland in the year 815; and it is now more than two leagues from the ſea. The ſame change has happened at Maguelone. The greateſt part of the vineyard of Agde was covered, about 40 years ago, with the waters of the ſea. In Spain, the ſea, within theſe few years, has retired conſiderably from Blanes, from Badalona, from the environs of the river Vobregat, from Cape Tortoſa along the coaſt of Valencia, &c.

The ſea may form hills and mountains, 1. By tranſporting earth, ſlime, ſand, and ſhells from one place to another: 2. By depoſiting ſediments compoſed of ſmall particles detached from the bottom and from the coaſts: And, *laſtly*, hills and downs may be formed by ſand and other particles driven againſt the coaſts by particular winds; theſe are gradually deſerted by the ſea; and

and become parts of the dry land. The downs of Flanders and Holland are of this kind. They consist of small elevations or hills, composed of sand and shells which have been blown from the sea upon the coasts. M. Barrere gives another example, which merits observation. 'The 'sea,' he remarks, 'by its motion, detaches im'mense quantities of plants, sand, shells, and 'slime, from its bottom, which are continually 'pushed by the winds and the waves towards 'the coasts. The perpetual repetition of this 'operation must give rise to gradual accumula'tions of new strata, which elevate the earth, 'produce downs and hills, enlarge the land, and 'confine the sea within narrower bounds.

'It is apparent that new strata of different 'materials must have been formed by the con'stant attrition of the waters, by the deposition 'of sediments, and by other causes, the operation 'of which has been co-eval with the existence 'of the globe itself. Of this we have a remark'able proof in the different strata of fossil shells, 'and other sea bodies, found at Roussillon near 'the village of Naffiac, which is 7 or 8 leagues 'from the sea. These beds of shells, which in'cline at different angles from west to east, are 'divided from each other by strata of earth and 'sand sometimes of a foot and a half, and some'times of two or three feet in thickness. In dry 'weather they seem as if sprinkled over with 'salt, and form a chain of hillocks from 25 to

'30 fathoms high. A long chain of hillocks of 'such a height could not be formed at once, 'but gradually, and by a long succession of time. 'Effects somewhat similar might have been pro- 'duced by an universal deluge. But, in this 'case, the different beds of fossil shells, instead 'of preserving a regular form, would have been 'blended together without any order.'

I entirely agree with the sentiments of M. Barrere, except as to the formation of mountains, which cannot be ascribed solely to those causes which increase the land, and diminish the boundaries of the ocean. On the contrary, I can produce several convincing arguments to prove that most of those eminences, which appear on the surface of the earth, have actually received their original formation in the sea itself: 1. Because they have corresponding angles, which necessarily imply the cause we have assigned, namely, the motion of the currents. 2. Because downs and hills, which have originated from materials thrown upon the coasts, are not, like common hills, composed of marble and hard stones. Besides, the shells found in the former are only in the fossil state; but those in the latter are entirely petrified. Neither is the position of the strata equally horizontal in downs, as in the hills composed of marble and hard stone. They are more or less inclined, as in the hills of Nassiac. On the contrary, in the hills and mountains formed by sediments under

under the waters of the ſea, the ſtrata are always parallel, and often horizontal; and the ſhells and other matter of them are completely petrified. I deſpair not of being able to prove, that the marbles and other calcareous bodies, which are almoſt all compoſed of madrepores, aſtroites, and ſhells, have acquired their denſity and perfection at the bottom of the ocean. But the tufas, ſoft ſtones, incruſtations, ſtalactites, &c. which are likewiſe calcinable, and have been formed ſince the earth was left dry, can never acquire the degree of denſity and of petrifaction peculiar to marble and other hard ſtones.

The remarks of M. Saulmon, concerning the *galets*, which are found in many places, may be ſeen in the hiſtory of the French Academy, *anno* 1707. Theſe *galets* are round, flat, finely poliſhed pieces of flint, thrown out by the ſea upon the coaſts. At Bayeux, and at Prutel, which is a league from the ſea, galets are found in digging pits and wells. The mountains of Bonneuil, of Brôie, and of Queſnoy, which are 18 leagues diſtant from the ſea, are covered with galets. They are alſo found in the valley of Clermont in Beauvois. M. Saulmon farther informs us, that a hole, 16 feet in length, was pierced horizontally into the high beach of Treſport, which conſiſts of a ſoft earth; and that, in the ſpace of 30 years, it was entirely obliterated by the ſea. Suppoſing the ſea to encroach

uniformly upon this ſhore, it will gain half a league in 12,000 years.

The motions of the ſea, therefore, muſt be regarded as the principal cauſe of all thoſe changes which have already happened, and of thoſe which are daily produced upon the ſurface of the earth. But there are other cauſes, which, though leſs conſiderable, have ſome effect in changing the ſuperficial parts of this globe. The rivers, the brooks, the melting of ſnows, the torrents, the froſts, &c. have given riſe to many alterations. The rains have diminiſhed the height of the mountains; the rivers and brooks have elevated the plains, and dammed up the ſea at their mouths; the torrents and the melting of ſnows have ſcooped out deep ravines or furrows in the valleys and narrow paſſages between the mountains; the froſts have ſplit rocks, and detached them from their original ſtations: Innumerable examples of revolutions produced by all theſe cauſes might be given. Varenius tells us, that the rivers tranſport into the ſea vaſt quantities of earth, and depoſite them at greater or leſſer diſtances from the ſhore, in proportion to the rapidity of their currents. Theſe portions of earth fall to the bottom, and firſt form ſmall banks, which, by conſtant acceſſions, become ſhoals, and at laſt appear in the form of fertile and habitable iſlands. It is in this manner that the iſlands in the Nile, thoſe in the river St. Lawrence, the iſland of Landa, ſituated near the

mouth

mouth of the river Coanza, on the coaſt of Africa, the Norwegian iſlands, &c. have received their exiſtence*. To theſe may be added the iſland of Trong-ming in China, which has been gradually formed by matters brought down by the river Nankin, and depoſited near its mouth. This iſland is more than 20 leagues in length, and from 5 to 6 in breadth†.

The Po, the Trento, and other rivers of Italy, bring down ſuch quantities of earth into the *lagunes* of Venice, eſpecially in the time of inundations, that they muſt be gradually filled up. Many parts of them are already dry during the ebb tide; and there is in them no depth of water, except in the canals, which are ſupported at an immenſe expence.

Large ſand-banks are thrown up at the mouths of the Nile, of the Ganges, of the Indus, of the Plata, and of many other rivers. La Loubere, in his voyage to Siam, informs us, that the banks of ſand and of earth augment daily, at the mouths of the great rivers of Aſia, and to ſuch a degree that the navigation of them becomes every hour more difficult, and will ſoon be impracticable. The ſame obſervation applies to the great rivers of Europe, and eſpecially to the Wolga, which empties itſelf by more than 70 mouths into the Caſpian, and to the Danube, which runs into the Black Sea by ſeven mouths, &c.

* See Varen. Geogr. p. 214.
† See Lettres Edifiant. rec. xi. p. 234.

As it ſeldom rains in Egypt, the regular inundations of the Nile proceed from the torrents which fall into it from Ethiopia. It brings down vaſt quantities of mud, which it depoſites annually not only upon the ſoil of Egypt, but throws it to great diſtances into the ſea, where it is laying the foundations of a new country, which muſt ariſe, in the courſe of time, out of the boſom of the ocean; for, upon ſounding at the diſtance of 20 leagues from the coaſt, the mud of the Nile is found at the bottom of the ſea; and every year it receives freſh accumulations. The Lower Egypt, now called the *Delta*, was formerly a bay*. Homer tells us, that the iſland of Pharos was a day and a night's voyage from Egypt; and now it is almoſt contiguous to the land. The ſoil of Egypt is not every where of an equal depth; it grows thinner the farther we remove from the ſea. Near the banks of the Nile, there are ſometimes more than 30 feet of good ſoil; but at the extremity of the inundation, there are not, perhaps, above 7 inches. All the cities of the Lower Egypt have been built upon artificial eminences †. The town of Damietta, which is now ten miles from the ſea, was a part of the ocean in the year 1243. The town of Foo[illegible]h, which, 300 years ago, was ſituated at the mouth of the Canopic branch of the Nile, is now 7 miles diſtant from it. Within

* See Diodor. Sic. lib. iii. Ariſtot. de Meteor. lib. i. cap. 14. Herodot. § 4, 5, &c.

† See Shaw's Travels.

40 years, the ſea has retired half a league from Roſetta, &c.*

Many changes have alſo taken place at the mouths of the great rivers of America, and even in thoſe which have been but lately diſcovered. Charlevoix tells us, that at the mouth of the Miſſiſippi, below New Orleans, the land runs out into a point, which appears not to be very ancient; becauſe, wherever the earth is dug, plenty of water is found; and beſides, the many little iſlands which have recently appeared in all the mouths of this river, leave no room to doubt that this point of land was formed in the ſame manner. It is certain, ſays he, that when M. Salle ſailed down the Miſſiſippi to the ſea, the mouth of this river was conſiderably different from what it is now.

The nearer, he adds, we approach the ſea, this difference becomes the more conſpicuous. There is no water in moſt of the ſmall channels cut in the bar by the river. Theſe channels are greatly multiplied by the trees brought down by the current. A ſingle tree, with its branches and roots, when ſtopped in a ſhallow part of the river, will entangle a thouſand. I have ſeen, ſays he, 200 leagues from New Orleans, different collections of trees, any one of which would fill all the wood-yards in Paris. Nothing can diſentangle them. The mud brought down by the river ſerves as a cement, and gradually

* See Shaw's Travels.

covers

covers them. Every inundation leaves a new ſtratum; and, in a few years, plants and ſhrubs begin to grow. It is in this manner that moſt points of land and iſlands, which ſo often change the courſe of rivers, are originally produced.

All the revolutions, however, produced by rivers, are very ſlow, and become not conſiderable till after a long courſe of years. But thoſe which are occaſioned by inundations or earthquakes are ſudden, and almoſt inſtantaneous. According to the Timæus of Plato, we are aſſured by the ancient prieſts of Egypt, 600 years before the birth of Chriſt, that there exiſted an iſland beyond the Pillars of Hercules, called *Atlantis*, which was larger than both Aſia and Lybia taken together; and that this great iſland was ſunk under the waters of the ocean by a terrible earthquake. 'Traditur Athenienſis civi-'tas reſtitiſſe olim innumeris hoſtium copiis quæ, 'ex Atlantico mari profectæ, propè cunctam 'Europam Aſiamque obſederunt; tunc enim 'fretum illud navigabile, habens in ore et quaſi 'veſtibulo ejus inſulam quam Herculis Columnas 'cognominant: Ferturque inſula illa Lybiâ ſi-'mul et Aſiâ Major fuiſſe, per quam ad alias 'proximas inſulas patebat aditus, atque ex inſu-'lis ad omnem continentem è conſpectu jacen-'tem vero mari vicinam; ſed intrà os ipſum 'portus angusto ſinu traditur, pelagus illud ve-'rum mare, terra quoque ille verè erat conti-'nens, &c. Poſt hæc ingenti terræ motu ju-

'gique

'gique diei unius et noctis illuvione factum eſt, 'ut terra dehiſcens omnes illos bellicoſos abſor-'beret, et Atlantis inſula ſub vaſto gurgite mer-'geretur.' *Plato in Timæo.* This ancient tradition is not devoid of probability. The lands ſwallowed up by the waters were, perhaps, thoſe which united Ireland to the Azores, and the Azores to the continent of America; for, in Ireland, there are the ſame foſſils, the ſame ſhells, and the ſame ſea-bodies, as appear in America; and ſome of them are found in no other part of Europe.

Two evidences are mentioned by Euſebius on the ſubject of deluges: The one is Melo, who affirms, that all the plains of Syria were formerly laid under water: The other is Abidenus, who ſays, that in the reign of King Siſithrus, there was a great deluge, which had been predicted by Saturn. Plutarch *De Solertia Animalium*, Ovid, and other mythologiſts, deſcribe the deluge of Deucalion, which happened, they ſay, in Theſſaly, about 700 years after the univerſal deluge. It is alſo alleged, that there was a ſtill more ancient deluge in Attica, during the time of Ogiges, about 230 years before that of Deucalion. In the year 1095, a deluge in Syria drowned a prodigious number of people*. In 1164, a deluge in Frieſland covered the whole environs of the coaſts, and drowned ſeveral thouſands of the inhabitants†. Another inun-

* See Alſted. Chron. chap. 25.

† See Krank, lib. v. c. 4.

dation, in 1218, deſtroyed 100,000 men. Of inundations there are many other examples.

Impetuous winds may be regarded as a third cauſe of changes on the ſurface of the globe. They not only give riſe to downs and hills along the ſea-coaſts, but they often arreſt rivers, make them regorge, and change their directions. They carry off cultivated lands, tear up trees, overturn houſes, and cover whole countries with ſand. Upon the coaſt of Brittany, in France, we have an example of theſe inundations of ſand: The hiſtory of the Academy, ann. 1722, deſcribes it in the following terms:

'In the environs of St. Paul de Leon, in 'Lower Brittany, there is a province on the ſea-'coaſt, which, before the year 1666, was inha-'bited; but now is totally deſerted, on account 'of the ſand, which has covered it to the depth 'of 20 feet, and which daily gains ground. 'Reckoning from the above period, the ſand 'has advanced about 6 leagues into the country; 'and it is now within half a league of St. Paul; 'and that town muſt probably ſoon be deſerted. 'The tops of ſteeples, and of ſome chimneys, 'ſtill appear above this ocean of ſand. The 'inhabitants, however, have always had leiſure 'to quit their poſſeſſions in ſafety. p. 7.

'This calamity is augmented by an eaſt, or a north wind, which elevate this fine ſand, and carry it in ſuch quantities, and with ſuch rapidity, that M. Deſlandes, to whom the Aca-

'demy

'demy are indebted for the obſervation, when 'walking in this country during an eaſt wind, 'found himſelf obliged to ſhake his hat and his 'garments from time to time, on account of the 'great weight of ſand with which they were 'loaded. Beſides, when the wind is violent, it 'carries the ſand over a ſmall arm of the ſea as 'far as Roſcof, a port much frequented by fo-'reign veſſels; and the ſand accumulates in the 'ſtreets of this village to the height of two feet, 'which obliges the inhabitants to drive it off in 'waggons. It may be further remarked, that 'the ſand is mixed with furruginous particles, 'which are recogniſable by the magnet.

'The coaſt which furniſhes this ſand extends 'from St. Paul to Plouefcat, a ſpace of more than 'four leagues; and it is nearly on a level with 'the ſea when the tide is full. It is ſituated in 'ſuch a manner that the eaſt and north-eaſt 'winds only can blow the ſand in upon the 'country. It is eaſy to conceive how ſand car-'ried and accumulated into any place by the 'wind, may again be taken up by the ſame 'wind, and carried ſtill farther. Thus the ſand 'may continue advancing, and covering new 'lands, as long as the magazine from which it 'originally proceeds ſhall remain unexhauſted; 'for, if the fountain were once dried up, the 'ſand, by advancing, would diminiſh in depth, 'and its deſtructive conſequences would gradu-

'ally

'ally decay. But it is not improbable that the 'sea may long continue to supply fresh sand, 'and keep this baneful magazine in a condition 'to do perpetual mischief.

'This disaster is not of an old date. Perhaps 'it was not till lately that the place was suffi- 'ciently stored to allow great quantities of sand 'to be carried off; or, perhaps, it has but re- 'cently been left uncovered by the waters. 'This coast has undergone some change. At 'present, the sea, at full tide, reaches half a 'league on this side of certain rocks, which it 'formerly never passed.

'This miserable province justifies what has 'been related, both by ancient and by modern 'travellers, that whole cities, and even vast 'armies, have been buried by tempests of sand 'in the deserts of Arabia.'

Mr. Shaw relates, that the ports of Laodicea, Tortosa, Rowadsa, Tripoly, Tyre, Acra, and Jaffa, are blocked up with sand transported by the high waves which rise on that part of the coast of the Mediterranean, when the west winds blow with violence*.

It is needless to give more examples of alterations on the surface of this globe. The fire, the air, and the waters, produce continual changes, which, in a succession of ages, become considerable. The sea and the land not only

* See Shaw's Travels.

change

change places from the effects of general and ſtated periodic laws, but a number of revolutions are occaſioned by particular and accidental cauſes, as earthquakes, inundations, ſinkings of mountains, &c. Thus the ſurface of the earth, which we regard as the moſt permanent of all things, is ſubjected, like the reſt of nature, to perpetual viciſſitudes.

CONCLUSION.

FROM the proofs delivered in Art. VII. and VIII. it appears to be an eſtabliſhed fact, that the whole ſurface of what is now dry land, was formerly buried under the waters of the ocean. It is equally clear, from Art. XII. that the flux and reflux, and other movements of the ocean, perpetually detach from the coaſts and from the bottom of the ſea, ſhells, and matter of every ſpecies; and that theſe are depoſited in other places in the form of ſediments, and give riſe to the horizontal ſtrata which every where appear. In the IX. Art. we have proved, that the inequalities on the ſurface of the globe have been occaſioned by the motion of the waters of the ſea; and that the mountains received their original formation from ſucceſſive accumulations of ſediments. It is likewiſe evident, from Art. XIII. that the currents which firſt followed the direction of theſe inequalities, afterwards beſtowed on them their preſent figure, namely, their alternate and correſponding angles. From Art. VIII. and XVIII. it appears, that moſt of the matters detached from the coaſts and from the bottom of the ſea were, when depoſited in ſediments, in the form of a fine im-

palpable

palpable powder, which entirely filled the cavities of ſhells, whether this powder was of the ſame nature, or only analogous to the matter of which the ſhells were compoſed. It is undeniable, from Art. XVII. that the horizontal ſtrata, which have been formed by ſucceſſive accumulations of ſediments, and which at firſt were ſoft and ductile, acquired denſity and compactneſs in proportion as they dried; and that the perpendicular fiſſures in the ſtrata derived their origin from the act of drying.

After peruſing Art. X. XI. XIV. XV, XVI. XVII. XVIII. and XIX. we muſt be convinced, that the ſurface of the earth has been disfigured by many revolutions and particular viciſſitudes, ariſing from the operation of the waters, and the effects of rains, froſt, rivers, winds, ſubterraneous fires, earthquakes, inundations, &c. and, conſequently, that the ſea has alternately changed places with the dry land, eſpecially in the firſt ages after the creation, when terreſtrial ſubſtances were much ſofter than they are at preſent. It muſt however be acknowledged, that our judgment concerning the ſucceſſion of natural revolutions cannot fail to be very imperfect; that we are ſtill leſs competent judges of thoſe changes which owe their birth to fortuitous events; and that the defect of hiſtoric records deprives us of the knowledge of particular facts. We deſiderate both time and experience. We never conſider, that, though our exiſtence here

be extremely limited, Nature proceeds in her course. We are ambitious of condensing into our momentary duration both the past and the future, without reflecting that human life is only a point of time, a single fact in the history of the operations of God.

END OF THE FIRST VOLUME.